MANAGEMENT EDITION

THE Petroleum Engineer

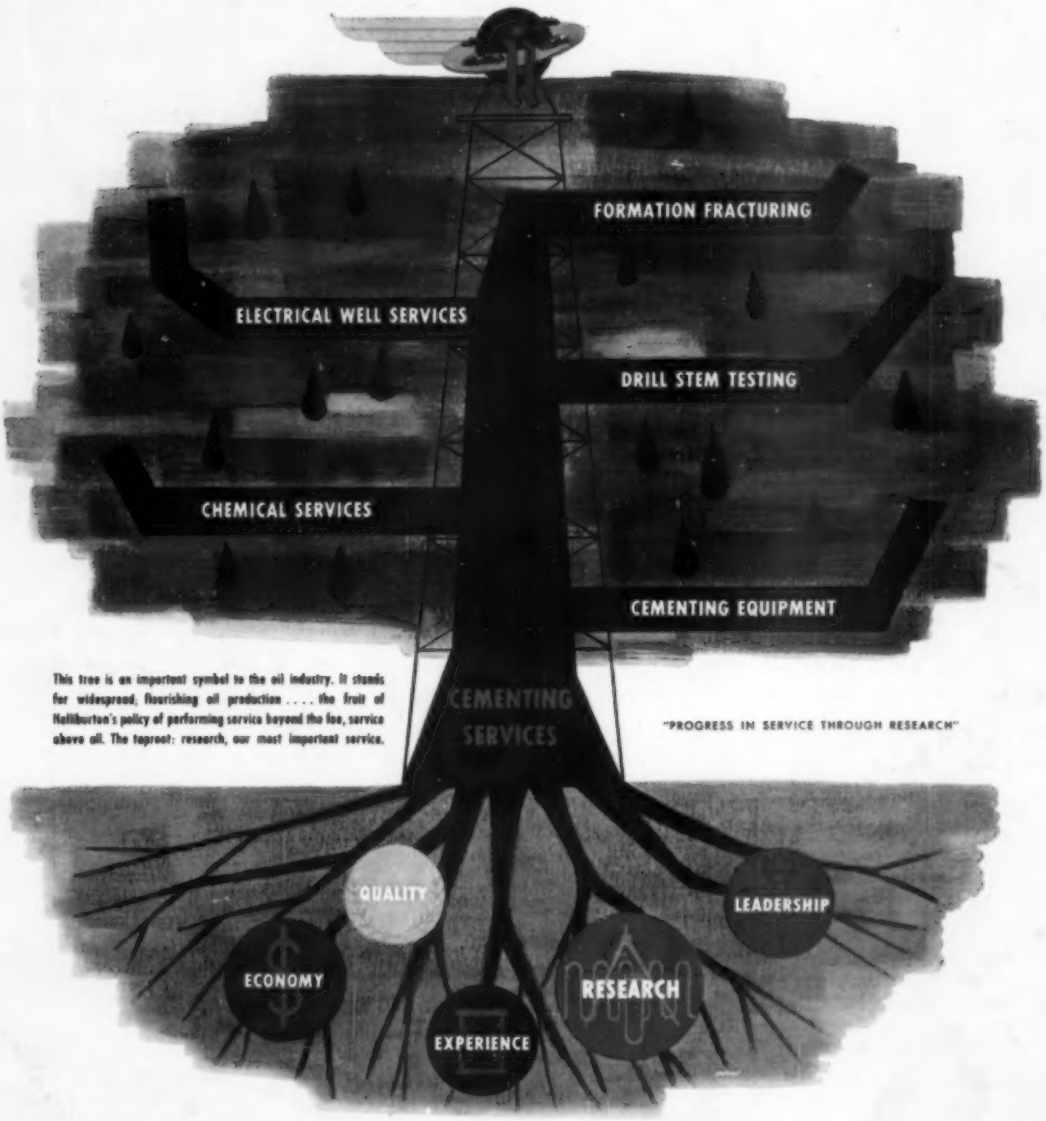
Exploration
Drilling
Producing

Refining
Petrochemical
Gas Processing

Oil . . Gas
Products
Pipelining

Signposts to Better Management
Troubles in Italian Oil Operations
The Helicopter — New Tool of the Petroleum Industry
How to Give Scholarships

THE HALLIBURTON TREE OF SERVICE



This tree is an important symbol to the oil industry. It stands for widespread, flourishing oil production . . . . the fruit of Halliburton's policy of performing service beyond the fee, service above all. The taproot: research, our most important service.

"PROGRESS IN SERVICE THROUGH RESEARCH"

HALLIBURTON OIL WELL CEMENTING COMPANY
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JUNE 1956

One Dollar A Copy

Dowell engineers use thickened crude oil with low fluid loss in Petrojel fracturing treatments.

DOWELL TREATMENT CARRIES SAND FARTHER INTO FRACTURES

PETROJEL*, an exclusive Dowell service, uses your own lease crude, diesel fuel or kerosene to give you an economical, efficient fracturing treatment.

The oil is mixed with special thickening agents in Dowell truck-mounted tanks or in your own lease tanks. The resulting Petrojel fluid has lower surface tension than the original base oil. This makes formation penetration and return of the fluid to the well bore easier. No gel-breaker is required. Additives also control fluid loss and oil thickness permitting sand to be carried farther into the fractures. The result—greater production.

What's more, Petrojel resists thinning at temperatures up to 200° F., making it especially effective in high temperature wells. You can use low treating pressures with Petrojel, too. Field use has shown it requires 500 to 2000 p.s.i. less pressure than other fracturing media when pumping through tubing.

For more information or service, call any of the 165 Dowell offices in the United States and Canada; in Venezuela, contact United Oilwell Service. Or write to Dowell Incorporated, Tulsa 1, Oklahoma, Dept. F-12.

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services for the oil industry

DOWELL

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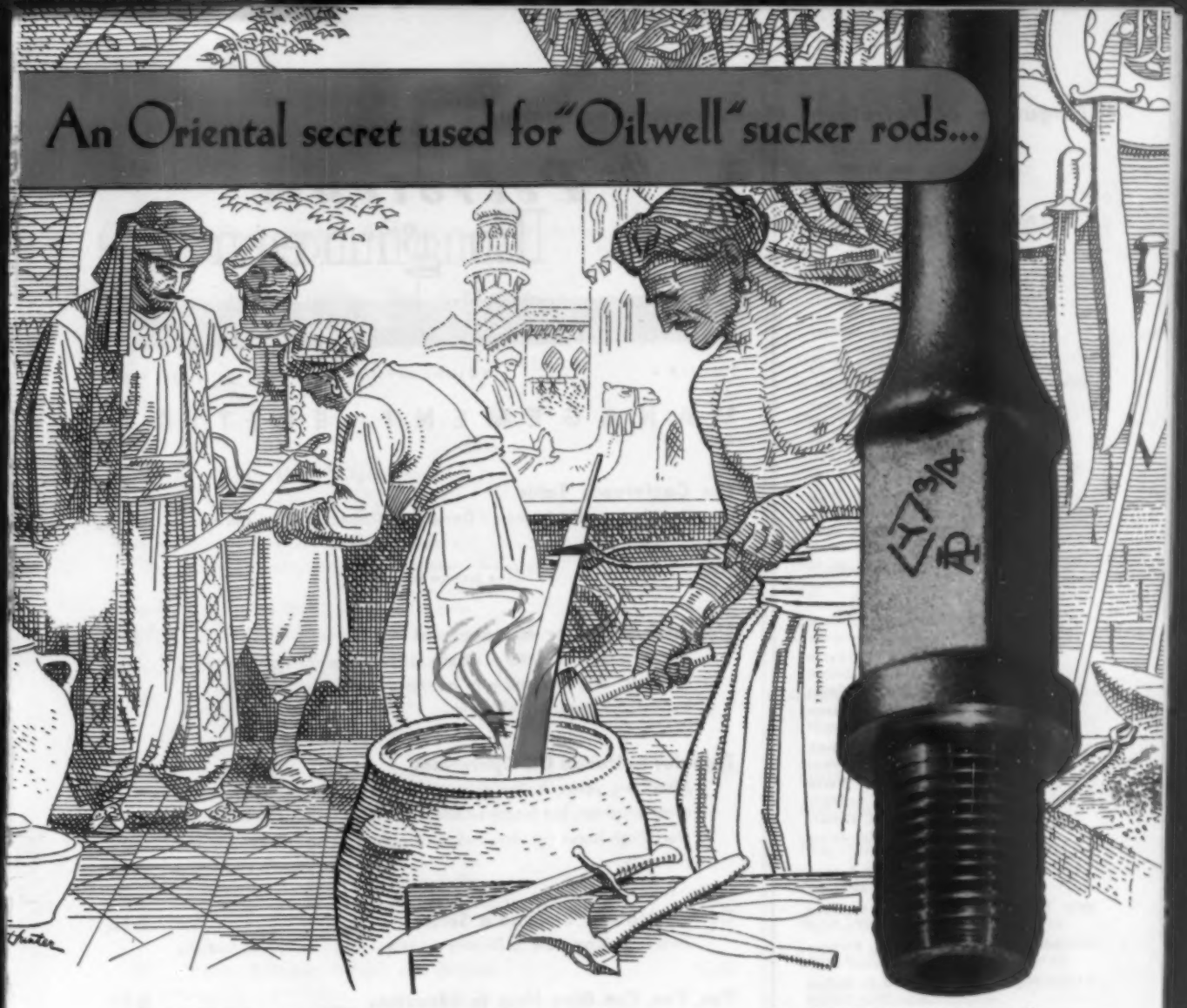
An Oriental secret used for "Oilwell" sucker rods...



LIQUID QUENCHING makes steel STRONGER!

SWORDS OF DAMASCUS were prized throughout the East for their ability to retain a sharp cutting edge and for their great strength, as well as their excellence of finish. Damascus sword-makers had discovered the magical steel re-forming properties of liquid quenching and used this secret to give outstanding merit to their handiwork.

Now this time-proved principle, with all the modern refinements which metallurgical science has devised, is used by "Oilwell" to give maximum strength, and resistance to fatigue to three grades of sucker rods—"T," "W," and "Y"—because only liquid quenching can capture the fine grain structure and optimum properties of the alloy steels used in these rods. No slower cooling method can impart the multiple properties demanded by so many deep well pumping applications of today.

These three rod grades differ in chemical composition and consequently in their characteristics and properties. For example, "W" rods have the greatest strength but "T" rods have greater resistance to H_2S corrosion and "Y" rods have superior fatigue characteristics at low cost when corrosive conditions are not present. Yet this additional heat-treating step improves the performance of each grade.

● *Specific service applications for all rod grades are shown in a Sucker Rod Comparison Chart which you may have for the asking. You pay no more for "Oilwell" liquid-quenched sucker rods than for non-quenched competitive grades . . . but get extra protection and longer service.*

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UNITED STATES STEEL

A Magazine of Petroleum Management Engineering

the Petroleum Engineer

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MANAGEMENT EDITION

DRILLING AND PRODUCING EDITION

REFINING AND PETROCHEMICAL EDITION

OIL AND GAS PIPELINING EDITION

The Real Powers of the Compact

IN the early 30's when over-supply shook the economic structure of the nation, the oil industry was drowning in its own product. Bonanza fields had brought waste and poverty to the industry.

Full pressure was on for federal control of all resources. Voters sought to put their livelihood — their very fate — into the hands of a popular administration. Powerful executive officers reached out to grasp the authority loosed by Congress and the public. The Secretary of Interior preached federal control of the oil industry and he wanted it right then.

Fighting this determined onslaught was a ragged hero — an industry beset by over-production and torn by steep, wide differences among its own groups.

Out of the one-sided struggle came the most preposterous government organization on record — The Interstate Oil Compact to Conserve Oil and Gas, signed in Dallas, Texas, February 15, 1935.

It was an organization with no authority: It could make no laws; it could punish no person or state; it could enforce no rules; it could collect no dues.

Yet this Compact of States was established to reduce chaos to order; to save oil that was carelessly lost to use; to make storage in the ground possible and production equitable; to develop practical, workable laws that protected petroleum operations and regulated production.

A most amazing thing happened — it worked! And it has been working ever since with increasing success.

NOW there has been a request by the Justice Department for funds to investigate possible price-fixing by the Compact. Actually, what would be investigated is not the small staff at the Oklahoma City headquarters but the regulatory bodies in the member states.

There are still determined forces who want the federal government to rule the petroleum industry. This is one more battle in the constant war between economic socialism and individual enterprise; another skirmish between Washington control and local regulation.

The industry 21 years ago might have got a subsidy for not seeking oil or for not producing what it found, as farmers were paid for plowing up every third row of cotton and killing every third pig. Of course, operators ran the risk that government payments might cease and that their ability to find oil might corrode, but you hardly think of that when you are trying to keep your head above a flood of oil.

Instead, however, state officials and oil men molded the Compact for self-regulation and self-improvement. Ever since it has been a protection for state and industry and, above all, for the nation. Without the Compact the United States could not have fueled World War II or met the Korean emergency.

We've said it had no authority — this town-hall of states — but it has some very great powers — the powers of good will and good sense, and these are very hard to investigate or control.

Ernestine Adams

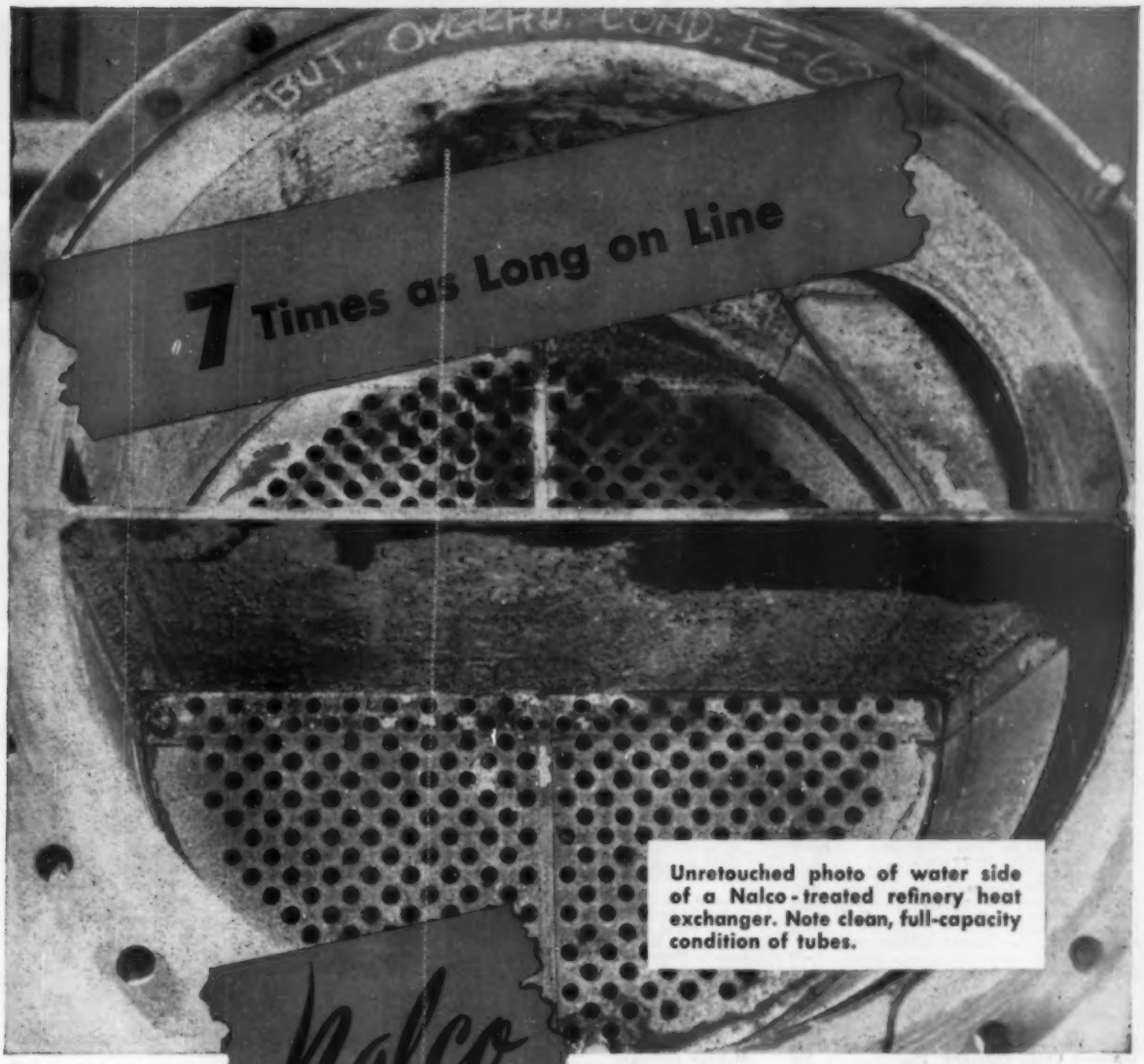
THE COMPACT PROBE

When Congress reapproved the Interstate Oil Compact, as it has done regularly since 1935, it included a policy declaration against limitation of production to fix prices of oil and gas.

This is the item that Antitrust Chief Barnes told the House would take 110 persons with three field offices and close to a million dollars to investigate.

Since the price of crude oil has had one small general rise in 8 years, the price of the probe seems high.

We're told by experts, however, the requested appropriations were too high because the Justice Department didn't want the job. We wouldn't know about this. It's already got too subtle for us: Investigating a price that didn't rise when practically everything else did.


7 Times as Long on Line
Unretouched photo of water side of a Nalco-treated refinery heat exchanger. Note clean, full-capacity condition of tubes.

SINCE Nalco TREATMENT TOOK OVER

This refinery heat exchanger was a prize example of plugging and corrosion headaches before Nalco System treatment was applied to the cooling water. After *7 times as long* as average previous runs, the exchanger was opened for inspection and found clean and corrosion free.

Consider your system. How much would you save by drastically cutting . . . perhaps even eliminating . . . the number of manual or mechanical cleanings of heat exchangers? Certainly it is substantial . . . more than enough to warrant writing or calling, TODAY, for more information from Nalco.

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Any way you look at it-

This Model OWL-50 two-stage unit was first set up as a single-stage unit for gas lifting one well near Refugio, Texas . . . then later moved to the Hobson Field and changed over to two-stage operation. It now handles about 250,000 cubic feet of gas per day with approximately 30 psi intake and 580 psi discharge pressures as part of a 15-well gas-lift system.

Lorain OWL Direct Connected Compressors

...give you extra advantages in the 20-50 hp range

UNITIZED CONSTRUCTION—Two-cycle, single-cylinder, wet-liner-type Lorain gas engine drives the compressor directly from the extended end of the engine crankshaft. Both units are mounted side-by-side on a strong cast-iron sub-base and working parts are fully enclosed in a heavily-ribbed one-piece frame, requiring minimum protection from the weather. Radiator for cooling both units, together with safety controls, etc. are mounted integrally.

SLOW SPEED—Both engine and compressor are of the slow-speed type, designed to give continuous full-load service with minimum field maintenance. Piston-type compressor incorporates standard crosshead construction. Mechanically-operated forced-feed lubricator has individual feeds which assure adequate lubrication at all operating speeds.

APPLICATION RANGE — Compressor cylinders can be furnished in single, two or three-stage types, capable of developing pressures up to 3,000 psi and are designed with top suction and bottom discharge connections. 20, 30, and 50 hp sizes are available.

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UNITED STATES STEEL

Petroleum Profile

AT 10, Ed Foss put aside his marbles and entered the oil business as an independent drilling contractor. The drill site was something like 10 ft from the west line and 20 ft from the south line of his folks' garage at their home in Glendale, California.

The drilling rig bore a strong resemblance to orange crates tossed out by the neighborhood grocer; the string of tools consisted of a cast-iron window weight and rope "borrowed" from the back bedroom window. Results of the well were disappointing. The hole was abandoned at a total depth of 12 ft when the bit struck water. And Ed Foss went back to his marbles.

Twelve years later, he was back in the oil business for keeps — as a budding young mechanical engineer fresh from California Institute of Technology. After three depression years as an oil field roughneck in California fields, he joined the former Barnsdall Oil Company in 1935 as a junior engineer.

In five years, he was Barnsdall's chief engineer; in two more, he was production superintendent in California; in three more years, he was named vice president in charge of West Coast production operations, a position he held when Barnsdall was merged into the Sunray organization in 1950.

Today, as vice president in charge of production for Sunray Mid-Continent Oil Company, in Tulsa, Oklahoma, Ed Foss directs a 1200-man department involved in production activities in 12 oil states.

R. E. (ED) FOSS
Vice President
Sunray Mid-Continent Oil Company

The youthful, silver-haired vice president has recently discovered new outlets for his mechanical engineering training. With two teen-age sons, one who has been bitten by the contagious 'hot-rod' virus, Foss finds himself serving more and more as a mechanic's helper on souped-up jalopies. Like so many fathers who found that if they couldn't whip the hot-rod craze they might as well join it, Ed has been a backer of a "strip' that understanding Tulsans provided for teen-age drivers.

Ed's younger son still prefers model boats and, like his older brother, gets an assist from dad. An amateur radio operator who calls himself a ham but who has to be rated a proficient technician, Ed rigged a radio-controlled boat for his son recently and just naturally had to operate the controls from the lakeside to see that everything was functioning. It used to be electric trains. When the boys' interests in cars and boats diminishes, the three head for Oklahoma's Fort Gibson to work on a cabin they are building.

Besides his duties as vice president of Sunray Mid-Continent and his job as right-hand man to his sons, Foss finds time to serve as a member of the board of directors of IPAA, on the general committee of the division of production in API, as vice chairman of the committee of vocational training in the API's division of production, as a member of AIME, the Petroleum Club of Tulsa, and the Tulsa Club. The Foss' are Episcopalians.

Six-feet-one and angular, Foss weighs in now at 180 lb, 5 lb lighter than during his football-playing days at Cal Tech, where he held down a tackle spot. An engineer with the personality of a salesman, Ed Foss is a thorough executive, able to put his finger on hundreds of wells scattered throughout the oil patch, and a man who always finds time to hear out a young engineer with a good idea.

Young engineers have always remained close to the heart of Ed Foss, perhaps because of his interest in his sons' activities. Foss has interviewed hundreds of youthful engineers-to-be and has hired a good number of them. He has a deep concern about the engineer shortage that is plaguing the oil industry and the nation; and he uses every opportunity to convince young men of the bright future for engineers. The industry has few men more devoted than Foss to the job of selling young men on engineering . . . and assisting them once they're sold. The magic appeal that wins these youths is simple. In Ed Foss, aspiring young engineers find a success story worth imitating.

BEHIND MILLIONS OF BARRELS OF PRODUCTION

Financing by the Republic

The nation's oil reserves are millions of barrels richer because of production loans made by the Republic. With a record of service to oil men equaled by few other banks in the nation, Republic's Oil Department is constantly seeking new opportunities to serve the petroleum industry.

WHAT CAN *WE* DO FOR *YOU*?

REPUBLIC National BANK of Dallas

MEMBER FEDERAL DEPOSIT INSURANCE CORPORATION

CAPITAL AND SURPLUS $70,000,000 • LARGEST IN THE SOUTH

THE CONFERENCE TABLE

"A rose by any other name is not a rose." —ANON

Decisions—Decisions—Decisions!

During the fight to free natural gas producers from FPC control, many of us pointed out that the Supreme Court's decision followed a new trend of centralization of government.

The Natural Gas Act of 1938 specifically stated that its regulations did not apply "to the production or gathering of natural gas." Before the Phillips decision, it was hard for those in the industry to conceive that there could be any opinion except one excluding producers from control.

When the Supreme Court legislated FPC control of gas production, the fact received small attention outside the petroleum industry. The struggle for freedom was all ours.

Now we have a broader view of our problem. Where once we led an advance with unprotected flanks, now we are in a multiplied force setting out to correct a trend toward law by oligarchy.

One imposing group to join the ranks is the National Association of Attorneys General. By a vote of 28 to 12, it went on record as favoring limitation of the power of the Supreme Court to determine whether Federal laws supersede state statutes.

FPC control of gas production inevitably came in conflict with state conservation laws. In addition to its other problems, the industry could end up paralyzed in a jurisdictional fight between Federal and State governments. Or perhaps you would say the producers could always depend upon the Supreme Court supporting Federal controls.

But could you? You can't know where you are with such a free-wheeling body.

Last fall it ruled the New Haven Railroad must pay $90,000 to an injured brakeman. In May, this year, the court reversed the decision and sent the case back to a lower court. The railroad had paid and the brakeman had already spent a large part of the money he received.

Justice Sherman Minton, the same one who gave the majority opinion in the Phillips case, changed his mind about the railroad case and reversed the 5 to 4 decision.

Change is vital to progress in any society but change in a Republic should be orderly and based on law; it should not be a decision of five men.

●

Dollar Diary. American Air Filter, Louisville, Kentucky, gives its employees this breakdown of where their work goes to provide for company expenses. It might work for you.

- 152 days' work to pay for wages, salaries, commissions and benefits for 2390 employees.
- 127 days' work to pay for materials used in manufacturing and assembling our products.
- 42 days' work to pay for supplies and services.
- 24 days' work to pay for the various taxes.
- 13 days' work to finance future growth of the company.
- 8 days' work to pay dividends to the 2223 owners who have invested their money in AAF.

Quality of Management

In his "Rockwell Report," W. F. Rockwell, Jr., points out the need of continuous good management:

> People are expressing more and more interest in the quality of management of the companies they work for, invest in, or buy from.
>
> And this interest goes beyond the question: "Is the company well managed *now?*" There is more and more concern with: "Who will be running it ten, fifteen, or twenty years from now?"
>
> We believe this is all to the good because it serves to keep management aware that adequate provision for *continuity* of good management is a primary responsibility to employees, shareholders, and customers.
>
> In our own company we utilize two factors, mainly, to build and maintain a reserve of management potential. The first is a continuous program of evaluation aimed at discovering men with leadership qualities.
>
> The second is our organizational structure itself, which provides the means of encouraging and developing these qualities.

●

Progress or Perish—Why do we spend our effort and time on trying to learn more and to achieve more? H. H. Hinson (Page E-3) says we progress or we perish. We change for the better or we change for the worse. We do not have the capacity to stand still any more than we have the ability to halt the present. The author names six ways to increase efficiency and tells why our economic system fails in other countries.

●

Twelve Tips — How many letters have you written? It almost scares you to think about the number, doesn't it? We've written thousands. We even wrote a book once on how to write letters but we learned something from the latest **Communications** article: Twelve Tips on How to Dictate a Letter. (Page E-13). Dr. Dennis Murphy has done it again!

●

Trouble in Italy—Politics have a firm grip on Italian oil and gas operations. Dr. Fernando de Mattia presents a brief background of an oil history that goes back to a gas explosion in 91 B. C. The article is primarily concerned with vast possibilities of oil supplies, top heavy refining capacity, mushrooming demand; there are hopes that crippling laws will release their hold on a struggling industry. (See Page E-7).

In case you haven't seen this jibe at management, here it is. What percentage of your plans does it fit?

PLAN AHEAD

Earnings Up 20% in First Quarter

Earnings are running 20 per cent higher than last year, according to first quarter financial reports of 55 companies. Last year's rise over 1954 was 17 per cent. Gross income rose 13 per cent for the 42 firms that provided that information, too.

Companies going over the $20 million net income mark for the first three months in 1956 were: Jersey Standard, Texas Company, Gulf, Socony-Mobil, Standard of California, Standard of Indiana, Shell, Phillips and Sinclair.

Largest percentage increases in earnings were scored by smaller companies; Woodley, Monterey, Union Oil and Gas of Louisiana, White Eagle, Hancock and Anderson-Prichard.

Coming next month is a valuable table on capital assets of oil companies, stockholders' equities, and rate of capital expenditure.

●

Another Education Aid. Nearly every company would like to help educate young men and women preparing for the future. They all do provide tax funds, of course. This new project, under National Association of Manufacturers' sponsorship, supplies a method for giving merit scholarships to college students. You'll be interested in learning how it's done even if you are using another method. (See Page E-17).

In the Year 2055

Predictions of 1 to 20 years are fairly common and the authors can possibly be held accountable. Sir George Thomson, F.R.S., Sc.D., has made a 100-year forecast in "The Foreseeable Future" (printed in Great Britain by Spottiswoode, Ballantyne and Company, London, $2.50) and he could be pretty imaginative without fear of personal contradiction. He has passed this interesting opportunity to soar into a dream world and conducted a pedestrian pace through energy, materials, communications, food, biology, social trends.

Sir George, Master of Corpus Christi College, Cambridge, gives a "conservative guess" of 10,000 million tons as ultimate oil reserves. This is about 1/13 what Wallace E. Pratt estimates. The author received the Nobel Prize for Physics in 1937. He mentions that geology is not an exact science. It isn't; everybody seems inclined to under-rate its generous clues.

THAT 6%

I have a little gas well
That is four miles deep;
It cost 2 million sawbucks
And it makes a million cubic feet.

Now, Mr. FPC, yer honors,
There's only one price feasible;
That gas must bring 3 bits per M
To get my "just and reasonable."

STILL GOING UP

55 Companies Earn
$775,405,000 . . . . up 20%

42 Companies' Revenues
$3,517,693,000 . . . up 13%

FINANCIAL REPORTS FOR FIRST QUARTER, 1956

Company	Gross income $1000 1956	1955	Per cent of 1955	Net income $1000 1956	1955	Per cent of 1955
Amerada	28,894	26,897	107	7,623	6,400	119
American Maracaibo	2,231	1,707	131	608	494	123
Anderson-Prichard	15,951	13,573	118	1,353	611	221
Argo Oil	3,200	2,954	108	1,250	1,168	107
Ashland Oil & Ref.	7,491	6,225	120	3,651	3,043	120
Atlantic Refining	149,419	143,405	104	12,223	9,821	123
Bishop Oil	720	468	154	118	69	171
Chicago Corp.	—	—	—	2,346	2,070	113
Cities Service	267,032	249,410	107	18,180	14,075	129
Colorado Oil & Gas	6,877	5,308	130	533	405	132
Continental Oil	144,635	129,910	111	13,794	12,142	113
Crescent Corp.	—	—	—	303	225	135
Delhi-Taylor	16,467	13,387	123	1,106	633	175
General Crude	3,275	3,280	100	900	957	94
Gulf Oil	—	—	—	69,319[1]	45,320	153
Hancock Oil	14,287	10,763	133	2,936	1,229	239
Honolulu Oil	—	8,655	—	3,479	3,202	109
Husky Oil	7,693	5,769	133	478	289	165
Louisiana Ld. & Exp.	6,727	6,225	108	3,605	3,375	107
Maracaibo Oil	559	483	116	144	104	138
Middle States	2,684	2,706	99	325	345	94
Mid West Oil	3,921	3,470	113	1,788	1,597	113
Monterey Oil	4,488	1,798	250	328	84	390
Ohio Oil	73,021	65,790	111	11,771	10,379	113
Panhandle Oil	3,541	3,134	113	287	211	136
Phillips Pet.	258,879	212,256	122	28,332	22,110	128
Plymouth Oil	—	—	—	2,263	2,204	103
Pure Oil	—	122,876	—	9,184	9,429	97
Quaker State	14,102	12,930	109	525	602	87
Richfield Oil	61,797	59,967	103	7,512	7,141	105
Seaboard Oil	—	—	—	2,012	1,689	119
Shamrock O. & G.	12,381	9,905	125	2,573	2,126	121
Shell Oil	401,626	354,000	113	35,010	28,585	122
Signal Oil & Gas	—	—	—	2,310	2,624	88
Sinclair Oil	316,650	281,791	112	24,246	21,208	114
Skelly Oil	62,909	55,980	112	8,033	7,698	104
Socony-Mobil	—	—	—	62,000	52,000	119
Southern Prod.	4,445	4,272	104	1,277	1,230	104
Standard Calif.	360,993	312,400	116	61,494	53,131	116
Standard Ind.	486,153	445,685	109	41,378	34,951	118
Standard N. J.	—	—	—	205,000	177,000	116
Standard Ohio	—	81,161	—	6,517	6,080	107
Sun Oil	—	—	—	12,255	11,722	105
Sunray Mid-Con	—	—	—	11,300	8,500	125
Superior Oil[2]	22,378	20,209	111	1,134	2,587	44
Texas Co.	501,774	428,395	117	69,598	56,021	124
Texas Gulf Prod.	4,240	3,954	107	1,797	1,855	97
Texas Pacific	6,138	5,986	103	2,055	2,023	102
Tidewater	131,744	121,026	109	9,037	8,083	112
Union of Calif.	93,344	82,074	114	7,030	7,107	99
Union O. & G. of La.	7,076	5,467	129	1,238	354	350
Universal Consol.	1,556	1,037	150	898	502	179
White Eagle Oil	2,287	2,822	81	147	46	320
Wilcox Oil	2,711	1,971	138	300	223	134
Woodley Pet.	1,397	899	155	502	94	534
Totals	**3,517,693**	**3,119,688**	**113**	**775,405**	**647,173**	**120**

[1]Includes estimated earnings for Warren for March, 1956.
[2]Second quarter of fiscal year, ending 2/29/56.

HIGHLIGHTS ★ ★ ★

Digest of News and Comment

A daily oil productive capacity of 10,000,000 bbl will be reached by January, 1957, the Independent Petroleum Association of America predicted. The group has forecast "a continued expansion in the availability of oil from domestic sources," as seen by a 534,000 bbl daily increase during 1955. IPAA also foresees an improved outlook for general business activity, and noted that total domestic and export oil demand for the year now stands at 9,197,000 bbl a day — an upward adjustment of 200,000 bbl daily over estimates made last October.

★ ★ ★

Legalization of gasoline price talks between oil firms and their dealers may prove the answer to gas price wars, Dwight Colley, vice president, Atlantic Refining Company, told New England marketers that the public needs protection from price fixing, but he sees no excuse for "violent price gyrations that shake gasoline retailers out of their stations." Atlantic suggested retail gasoline prices in Pennsylvania, with resulting better service and a degree of price stabilization.

★ ★ ★

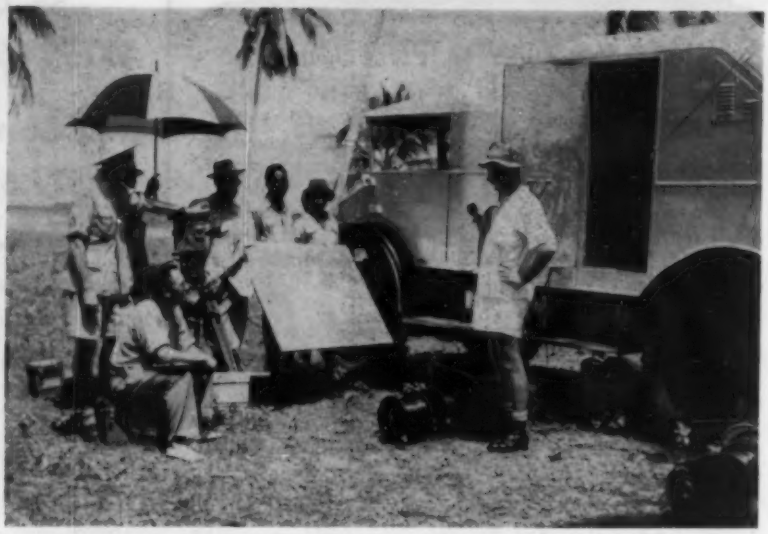
Seven school teachers from the Tulsa, Oklahoma, school system have accepted offers of summer employment on the research staff of Stanolind Oil and Gas Company for the coming summer months. The action, say company officials, will contribute to Stanolind's research effort and at the same time give teachers a first-hand knowledge of the opportunities open to technically-trained people in industry and aid them in their efforts to channel more students into scientific and engineering fields.

★ ★ ★

World petroleum production estimates will now be accessible only to the director of the new all government-staffed Foreign Petroleum Supply Committee, in an "antitrust" attempt limiting the amount of compiled information available to oil companies. Defense Mobilizer Flemming has asked 13 major oil concerns to continue participation in the program and "abide by the rules," not to make quota agreements.

★ ★ ★

Engineers and Scientists of America, an independent union claiming to represent some 40,000 professional workers, turned down recent proposals to affiliate with the AFL-CIO. The group has also rejected a proposed merger with the federation's American Federation of Technical Engineers. General opinion of the ESA is toward pure professionalism, possibly barring technicians from membership in the group.



Exploring for Oil takes on an out-of-this-world haze when it is in the country of Zanzibar and when explorers pose for films as they work. The picture, "*The New Explorers,*" tells the story of British Petroleum Company's search for oil in the Persian Gulf, Canada, Zanzibar, Papua, Trinidad and Sicily. Nearly 15,000 stockholders and staff of the company filled eight of London's biggest theatres recently to see this and two other company-produced films.

World's deepest oil well has reported a settled production of 134 bbl daily of 38 deg crude. The well, No. 1-L Louisiana Land Company-Humble, is owned by Richardson & Bass, Freeport Sulphur Company and John Mecom. It is producing from 21,433-65 ft through a 9/64-in. choke. Flowing tubing pressure has decreased to 2000 psi.

★ ★ ★

Americans working in Great Britain may soon be subject to British taxation on their full salary. A finance bill being considered by Parliament would change existing rules which made taxable only the portion of their income that is actually paid them in Britain. The change is being sought to cover salaries banked in the U. S. but not taxed by either government.

★ ★ ★

Off-duty education of Delhi-Taylor Oil Corporation employees will be paid for by the company. Aimed at encouraging further education through academic institutions, assistance is being offered to all the company's full-time employees. Full tuition will be paid for courses that directly benefit the employee's job and half the tuition on other company-approved courses.

What Makes a Man Work?

In great demand by readers are reprints of the article "What Makes a Man Work?" by Dr. A. Q. Sartain, published in the March 1956 issue of The Petroleum Engineer.

The article is a penetrating answer to a key question asked by management from top to lower levels: What produces the all-important morale that inspires good work? It has received high praise from management in petroleum and other industries. Scores of requests have been received and a reorder of reprints has been filled.

For those interested in obtaining copies the price is:

1 to 10 copies ..... 25 cents each
10 to 50 copies ..... 15 cents each
50 or more copies ... 10 cents each

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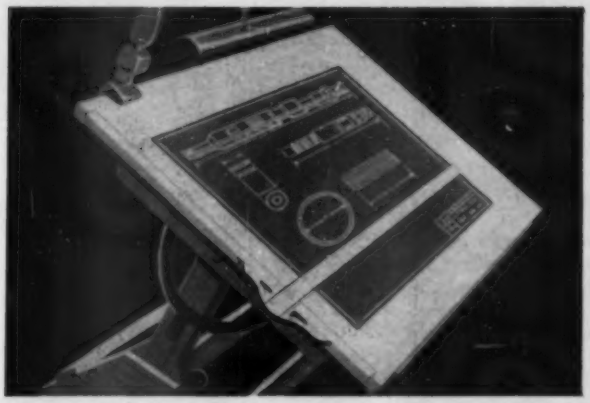

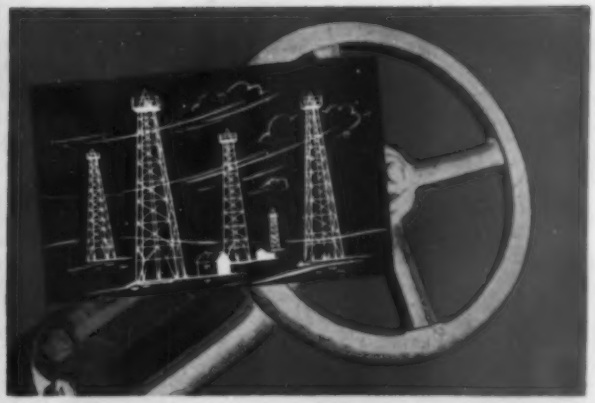

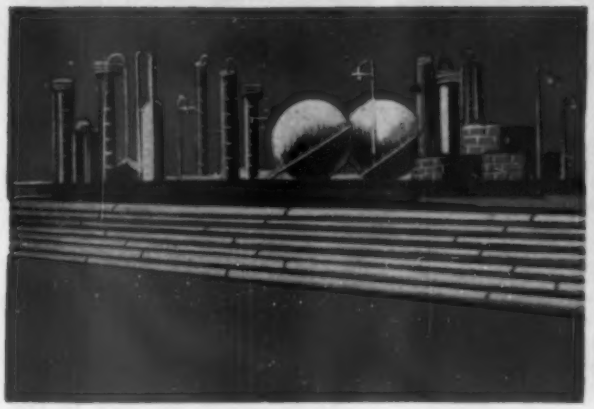

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Louisiana's oil production allowables are approaching an economic minimum, Conservation Commissioner John Hussey has warned the oil industry. The Pelican state has already prorated its wells more than any other state, Hussey says, in an attempt to make a place for the tremendous influx of new discoveries and development wells being completed.

★ ★ ★

Libya will soon see a large exploration program by Texas Gulf Producing Company and W. R. Grace & Company. Some 25,000,000 acres comprise the concession awarded to Libyan American Oil Company, a subsidiary of Texas Gulf. A well is being drilled in the Gerdes el Abid section of Cyrenaica.

★ ★ ★

No oil for the Tars, says the House Appropriations Committee. Navy was denied $529,000 for exploration for oil on San Nicholas Island, California, as "there appears to be no authority or justification for the proposed exploration and drilling." The Committee, in its Defense Department appropriation bill sent to the House recently, recommended only $683,000 for the Naval petroleum reserves for the coming fiscal year. This marks a reduction of $2,168,000 for this purpose in the current year.

★ ★ ★

Pennsylvania grade crude has received its third price boost this year to bring Bradford District crude to $4.45 per barrel. Most recent increase, announced in mid-May by the Joseph Seep Purchasing Agency, was due to heavy refiners' demand for the oil coupled with a smaller supply from producers' runs. The 25 cent-a-barrel hike brought the Penn grade price to $4.32 in the Middle District, Southwest grade to $4.03 and Eureka grade to $3.91.

★ ★ ★

Supreme Court has been asked by the Federal Government to stop Louisiana's fight for its tidelands in the state court. Attorney General Brownell says the dispute is now pending in the high court and must be decided there. Louisiana has been given until June 25 to reply to government's appeal for Supreme Court judgment, which will probably be argued when the court is reconvened next fall. Louisiana moved last month in a state court to stop federal leasing of land within the 10.5-mile offshore limits. A state district court decree put a temporary injunction on federal leasing, scheduled to begin May 15. This sale was postponed.

★ ★ ★

Oil imports study will prob- ably be completed by September by the President's fuels policy committee, Defense Mobilizer Flemming has advised importers. In a letter to them Flemming indicated that this re-examination will be made by the four consultants who laid the groundwork for the original voluntary program, relating imports to 1954 domestic crude production. These are J. F. Brownlee, economist; J. Ed Warren, former deputy oil administrator, C. J. Potter, National Coal Association, and Federal Judge Wilkins.

★ ★ ★

Oil and gas depletion may need to fight for its present status — if not for its life — following the recent seating of its opponent, Senator Douglas of Illinois on the Senate Finance Committee. Already on this committee is Senator Williams of Delaware, who has proposed a cut in the allowance to 15 per cent. Douglas gained a position on the Finance Committee upon the recent death of Senator Alben Barkley.

★ ★ ★

Taxes paid out of total in- come in 1952 takes a big bite out of every business—especially the oil and gas producers. According to U. S. Treasury Department statistics compiled by the IPAA, the oil and gas producers paid far more than their share of the tax load—almost twice the amount paid by the all-industry group. The black portions in the above coins represent Federal income taxes, and the shaded slices reveal the amount taken through state and local income, business and property taxes.

Oil industry problems should be solved within the oil industry, the National Oil Jobbers seem to agree. Strained relations by different segments of the oil industry were pointed out by the guest speaker at the NOJC mid-year meeting, D. T. Colley, vice president and general manager of marketing for Atlantic Refining Company, who called relations with government "never more precarious—more dangerous." The NOJC deferred judgment on the depletion allowance, which has little appeal with the group. An API announcement, made public during the convention, extending its support for gasoline tax collection at the jobber level made for more industry harmony.

★ ★ ★

Mid-Continent refiners have generally increased prices of regular grade gasoline a half-cent a gallon in May following distribution of higher octane number motor fuel. The gasoline now moving to northern markets from Oklahoma, Kansas and Arkansas are a minimum 88 octane, as compared with 86 octane previously.

★ ★ ★

Steel output dropped to the lowest point this year early in May. Much of the loss, which put the mills operating at 95.2 per cent of capacity, was blamed on the strike at the Tennessee Coal & Iron division of U. S. Steel at Birmingham, Alabama. Output of this unit is estimated at almost four million tons annually — about 3 per cent of the industry's present capacity. Many plants throughout the country are closing for needed repairs following nearly a year of peak-plus production.

★ ★ ★

Government is paving the way for too many oil imports, says IPAA President Robert Mood, that will "lead inevitably to increased dependency on foreign oil" at the expense of domestic industry. The Independent Producers took issue with Defense Mobilizer Flemming's proposals on import controls. Although warning importers against bringing in as much oil as they had scheduled during the second half of this year, Flemming said that imports into the West Coast would be excluded from calculations, as well as those from Venezuela and Canada.

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Yet down-time is short with Stratafrac. Liquid materials arrive at the well already mixed. Treatment is fast with minimum shut-in afterwards, and no gel breaker needed.

Stratafrac's unusual flexibility makes it effective in almost all types of formations. To match well conditions, Dowell engineers can vary acid and sand content, or add silicate control and clay dissolving agents. This double-action Dowell treatment has brought outstanding, *sustained* production increases to wells in almost every area.

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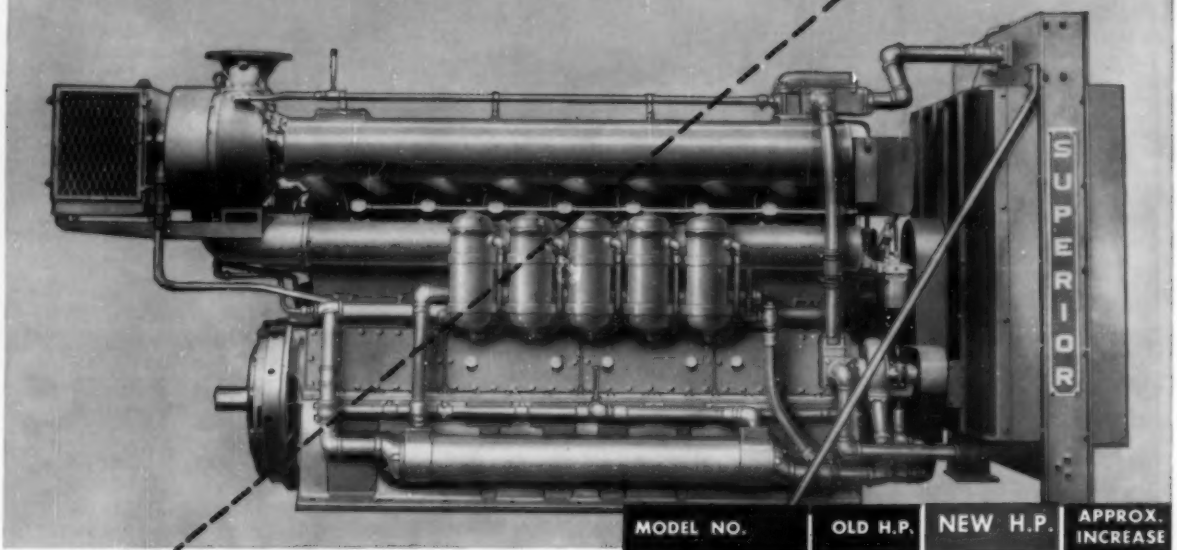

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Super PTD-8	375	485	29%
Super PTDS-6	460	560	22%
Super PTDS-8	620	750	21%

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Now, White's newly improved Super PTD Diesels give you even more drilling engine advantages than ever before! You get greater power with no increase in size . resulting in less weight and less cost per horsepower! You get greater working ability . . more lugging power for easier hoisting, and faster acceleration for quicker round trips and for fast pipe handling. They have plenty reserve power too for emergencies, and enable you to get more power from fewer engines on multiple engine rigs.

Super PTD's provide power comparable to other engines having more cylinders . thus, the more simple design with fewer cylinders and internal parts offers outstanding advantages in requiring fewer replacement parts and lower maintenance and repair costs.

White's new design and engineering advances have also achieved even greater dependability, smoother operation, increased engine life and highly improved engine efficiency. Get all the facts from leading rig manufacturers, or through White Diesel representatives available in all oil field areas, or through White Diesel Engine Division.

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Meetings

June 7-8—**DECHEMA,** 31st annual congress, Frankfurt-am-Main (West Germany).

June 10-11—**American Association of Oil-well Drilling Contractors,** Board of Directors Meeting, Paso Del Norte Hotel, El Paso, Texas.

June 10-15—**American Petroleum Institute,** Division of Production, mid-year standardization conference, Brown Palace and Cosmopolitan Hotels, Denver, Colorado.

June 11-12—**American Petroleum Institute,** division of production, midyear training committee meeting, Cosmopolitan Hotel, Denver, Colorado.

June 11-13—**Appalachian Underground Corrosion Short Course,** first annual meeting, School of Mines of West Virginia University, Morgantown, West Virginia.

June 13—**Pennsylvania Grade Crude Oil Association,** 33rd annual meeting, Pennhills Club, Bradford, Pennsylvania.

June 17-22—**American Society for Testing Materials,** Chalfonte-Haddon Hall, Atlantic City, New Jersey.

June 17-22—**Creative Engineering Seminar,** The Pennsylvania State University, University Park, Pennsylvania.

June 17-22—**American Society for Testing Materials,** Pacific Coast meeting, Hotel Statler, Los Angeles, California.

June 20-23—**American Association of Petroleum Landmen** second annual convention, Denver, Colorado.

June 21-22—**Western Petroleum Refiners Association,** regional technical-industrial relations meeting, Broadview Hotel, Wichita, Kansas.

June 25-29—**The American Society for Engineering Education,** annual meeting, Iowa State College, Ames, Iowa.

June 26-29—**Canadian Gas Association,** Manoir Richelieu, Murray Bay, Quebec, Canada.

June 28-30—**Rocky Mountain Oil and Gas Association,** mid-year meeting, Utah Hotel, Salt Lake City, Utah.

Aug. 20-Sept. 7—**Short Course in Colloidal Phenomena in the Petroleum Sciences,** Louisiana State University, Baton Rouge, Louisiana.

Aug. 23-25—**Alberta Society of Petroleum Geologists,** 6th annual field conference, Calgary, Alberta, Canada.

Sept. 7-8—**Association of Desk and Derrick Clubs of North America,** 5th annual convention, New Orleans, Louisiana.

Sept. 9-12—**American Institute of Chemical Engineers,** William Penn Hotel, Pittsburgh, Pennsylvania.

Sept. 10-14—**International Congress on Catalysts,** Bellevue-Stratford Hotel, Philadelphia, Pennsylvania.

Sept. 11-13—**Pacific Coast Gas Association,** annual meeting, Coronado, California.

Sept. 12-14—**National Petroleum Association,** annual meeting. Traymore Hotel, Atlantic City, New Jersey.

Sept. 12-14. **Third Annual Electrical Conference of the Petroleum Industry,** sponsored by American Institute of Electrical Engineers and Kansas City Section of AIEE, Kansas City, Missouri.

Sept. 16-18—**Pennsylvania Petroleum Association,** annual meeting, Pocono Manor Inn, Pocono Manor, Pennsylvania.

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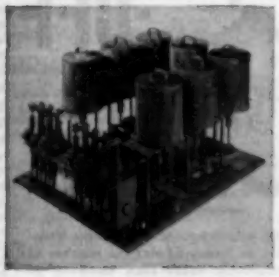

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Sept. 16-18—**New Mexico Petroleum Industries Committee,** annual meeting, Hilton Hotel, Albuquerque, New Mexico.

Sept. 16-21—**American Chemical Society,** 130th annual meeting, Atlantic City, New Jersey.

Sept. 16-22—**American Society for Testing Materials,** Pacific Coast meeting, Hotel Statler, Los Angeles, California.

Sept. 17-21—**Instrument Society of America,** annual, Instrument-Automation Conference and Exhibit (International), New York Coliseum, New York City.

Sept. 20-21—**Mid-Continent Oil and Gas Association,** La.-Ark. division membership meeting, Roosevelt Hotel, New Orleans, Louisiana.

Sept. 20-21—**Western Petroleum Refiners Association,** regional technical-industrial relations meeting, Hotel Henning, Casper, Wyoming.

Sept. 23-26—**American Society of Mechanical Engineers,** 1956 petroleum mechanical engineering conference, Statler Hilton Hotel, Dallas, Texas.

Sept. 26-28—**American Institute of Mining, Metallurgical & Petroleum Engineers,** Rocky Mountain mineral conference, Newhouse Hotel, Salt Lake City.

Oct. 1-5—**American Institute of Electrical Engineers,** Morrison Hotel, Chicago, Illinois.

Oct. 2-3—**Texas Mid-Continent Oil & Gas Association,** 37th annual meeting, Rice Hotel, Houston, Texas.

Oct. 7-9—**American Association of Oil-well Drilling Contractors,** 16th annual meeting, Texas Hotel, Fort Worth, Texas.

Oct. 14-17—**American Institute of Mining, Metallurgical and Petroleum Engineers,** fall meeting, Biltmore Hotel, Los Angeles, California.

Oct. 17-18—**Indiana Independent Petroleum Association,** Severin Hotel, Indianapolis, Indiana.

Oct. 18-19—**Western Petroleum Refiners Association,** regional technical-industrial relations meeting. Rufus Garrett Hotel, El Dorado, Arkansas.

Oct. 22-24—**Rocky Mountain Oil & Gas Association,** annual meeting, Cosmopolitan Hotel, Denver, Colorado.

Oct. 25-26—**Independent Petroleum Association of America,** annual membership, Mayo Hotel, Tulsa, Oklahoma.

Oct. 29-30—**Independent Petroleum Association of America,** 27th annual meeting, Statler Hilton Hotel, Dallas, Texas.

Oct. 29-Nov. 1—**Society of Exploration Geophysicists,** national convention, New Orleans, Louisiana.

Nov. 12-15—**American Petroleum Institute,** 36th annual meeting, Conrad Hilton Hotel and Palmer House, Chicago, Illinois.

Nov. 19-20—**North Texas Secondary Recovery Symposium,** Petroleum branch, AIME, Municipal Auditorium, Wichita Falls, Texas.

Nov. 25-30—**American Society of Mechanical Engineers,** Statler Hotel, New York City.

Dec. 9-12—**American Institute of Chemical Engineers,** annual meeting, Statler Hotel, Boston, Massachusetts.

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"Have Magic Suitcase ...Will Travel"

Every woman is interested in beauty—clothes—homemaking. But not every woman knows how big a part *oil* plays in a woman's world! That's why the Oil Industry Information Committee sponsors a Women's Program.

Today, hundreds of oilwomen—industry employees and oilmen's wives—help tell the story of oil in an interesting and dramatic way. The "Magic Suitcase" is one way. It contains products made from petroleum—cosmetics, detergents, oil-based "miracle" fabrics and many other items a woman uses in her daily life. This demonstration—as well as other lectures and displays—shows her how *oil* and *oil* products help make her look more beautiful and make her housework much easier.

The Women's Program is only one of many ways through which your OIIC helps show the public that it is best served by a privately-owned, fully competitive oil industry. If *you* would like to aid in the Women's Program—or another of OIIC's many activities—contact the OIIC in your area today. You'll not only be helping your industry but you'll get a wonderful sense of personal satisfaction from it as well.

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What makes Jersey Standard run? People. People in offices and in the labs, in the oil fields and refineries of our affiliated companies. People like all of us . . . who work, play, raise families.

What keeps Jersey Standard and its affiliates in business? All kinds of people – stockholders, employees and customers.

Because of all these people, we had a good year in '55. A year of searching for and finding more oil to provide light and heat, to run cars and trucks, trains and planes, buses and tractors, to make petrochemicals. A year of even greater research leading to more and better products. A year—as our Annual Report shows – of better sales and earnings, of record payments in wages and benefits to employees, of record income generated for governments in the form of taxes – a year, in short, of bigger contributions to the prosperity of the people of the countries where we do business.

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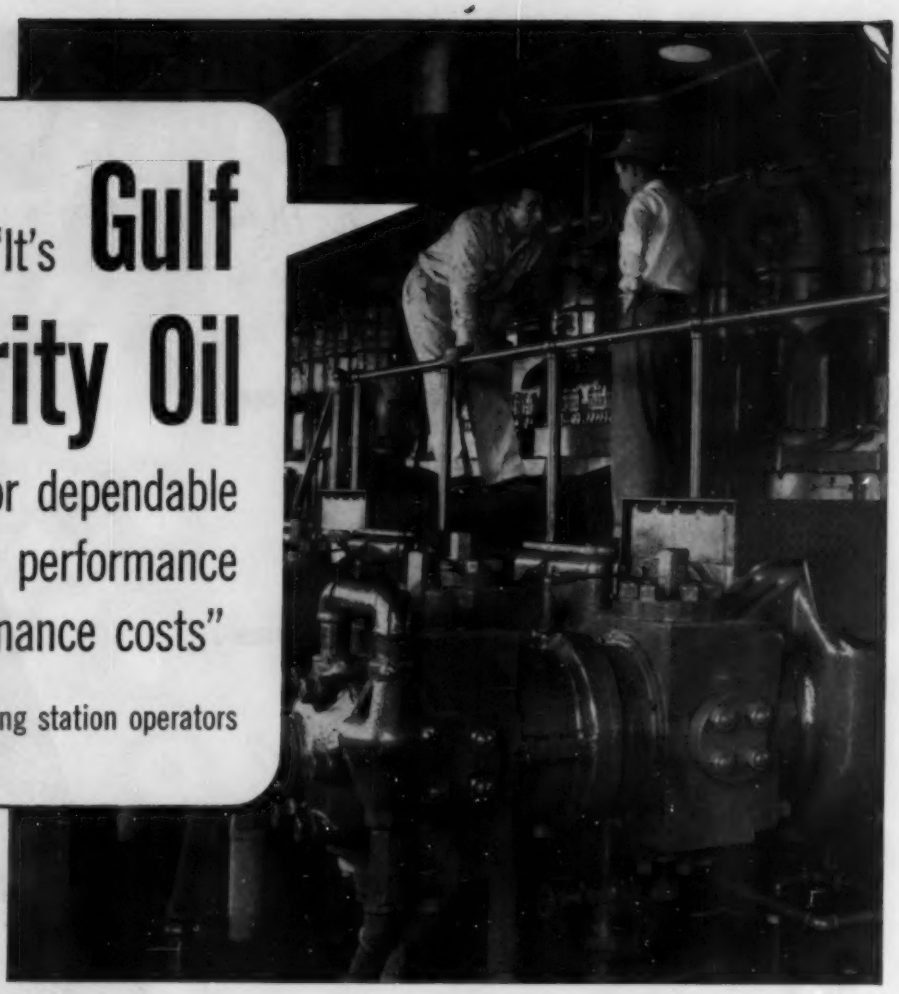
"It's **Gulf Security Oil** for dependable gas compressor performance and low maintenance costs"

say pumping station operators



Smooth, continuous operation is a must for these units in service at a South Texas gas compressor plant. They are responsible for the steady flow of essential natural gas through pipe lines to homes and industries as far north as Detroit and New York. Gulf Security Oil provides the sure, effective protection needed for cylinders and bearings in both engines and compressors.

You can depend on Gulf Security Oil to provide the proper lubrication that is so important to vital compressor units if operating troubles are to be prevented and maintenance costs kept low.

Gulf Security Oil has a record of outstanding performance in scores of gas transmission plants. After years of operation with this quality oil, the cylinders and piston rings of both the compressors and power assemblies show negligible wear. And few carbon deposits have formed on power cylinder ports and pistons.

If you are installing new compressor units, or feel that you're not getting the most effective lubrication possible for your present units, it will certainly pay you to try Gulf Security Oil. Contact your nearest Gulf Office and have a Gulf Sales Engineer call.

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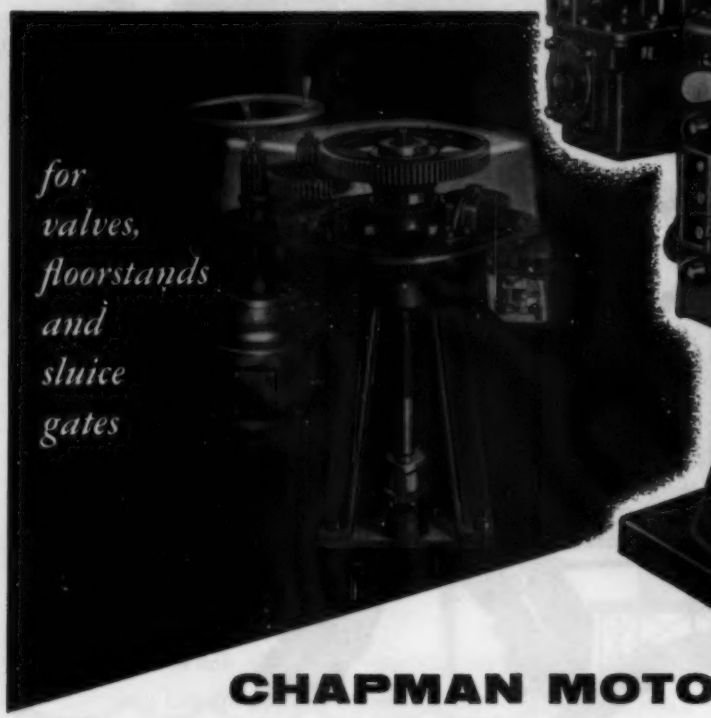

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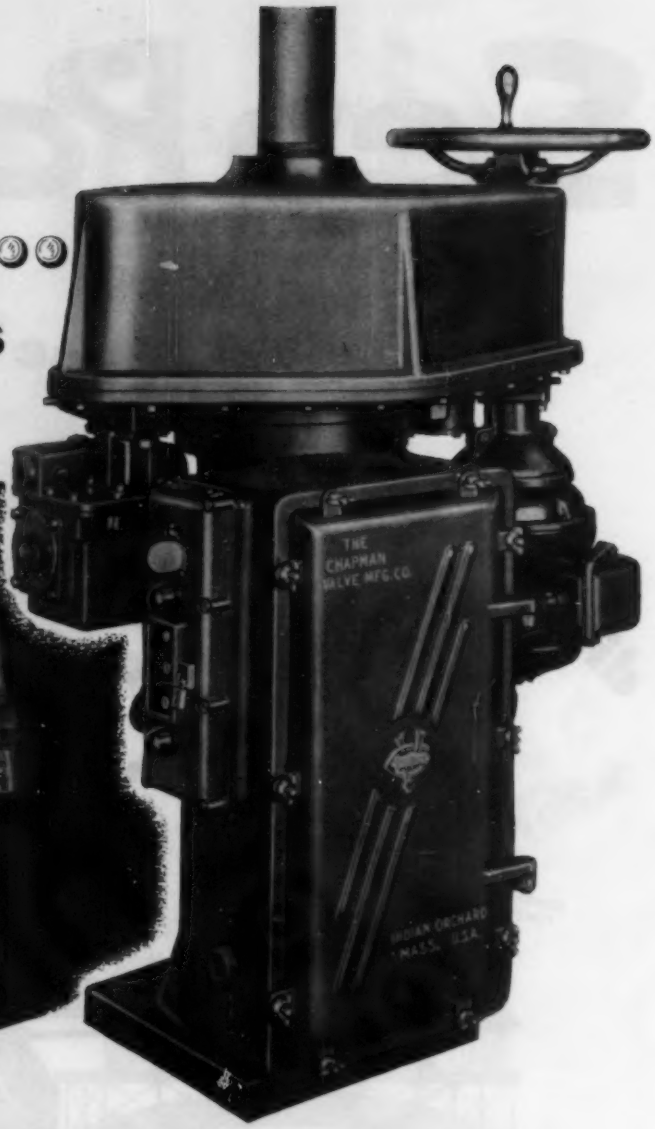

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With Chapman Motor Units your valves seat tight . . . but never too tight. Micrometer adjustment on limit switch insures exact tightness presetting. Drift is eliminated. Lash is slashed. Complete operation by low speed motors is always smooth, accurate and trouble free.

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Installation is quick and easy. Chapman Motor Units and Floorstands are wired and ready to tie in with your leads. Just hitch them up. You're in business.

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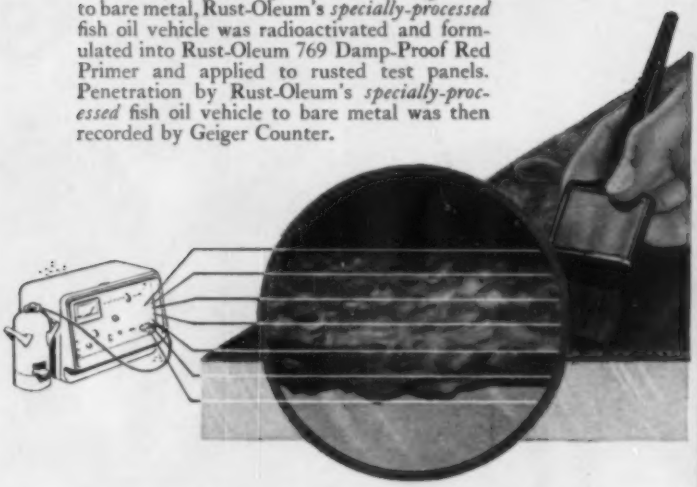
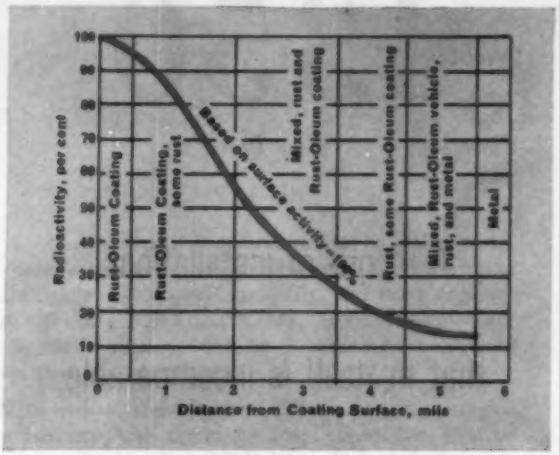
To trace Rust-Oleum penetration through rust to bare metal, Rust-Oleum's *specially-processed* fish oil vehicle was radioactivated and formulated into Rust-Oleum 769 Damp-Proof Red Primer and applied to rusted test panels. Penetration by Rust-Oleum's *specially-processed* fish oil vehicle to bare metal was then recorded by Geiger Counter.





It's easy to actually see Rust-Oleum penetration through rust to bare metal by following the curved line on the graph above. The curved line illustrates Rust-Oleum *penetration* at each mil level down to bare metal as recorded by Geiger Counter and Gas Flow Proportional Counter.

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Here's what

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The results of nearly three years radioactive research prove that Rust-Oleum's *specially-processed* fish oil vehicle penetrates through rust to bare metal.

This penetration enables you to stop rust, because the Rust-Oleum fish oil vehicle soaks through the rust to bare metal and into the tiny pits where it drives out air and moisture that cause rust. Because of this penetration, you can apply Rust-Oleum 769 Damp-Proof Red Primer directly over sound rusted surfaces—usually eliminating costly surface preparations. Rust-Oleum resists salt water, sun, fumes, heat, humidity, and weathering. Attach coupon to your letterhead for your thirty-page report entitled, "The Development of a Method To Determine The Degree of Penetration of a Rust-Oleum Fish-Oil-Based Coating Into Rust On Steel Specimens," as prepared by Battelle Memorial Institute technologists.

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There is only one *Rust-Oleum. It is distinctive as your own fingerprint.*

Rust-Oleum is *exclusive*, using a specially processed fish oil vehicle that penetrates rust to bare metal. Accept no substitute. Buy or specify Rust-Oleum. You'll be happy that you did.

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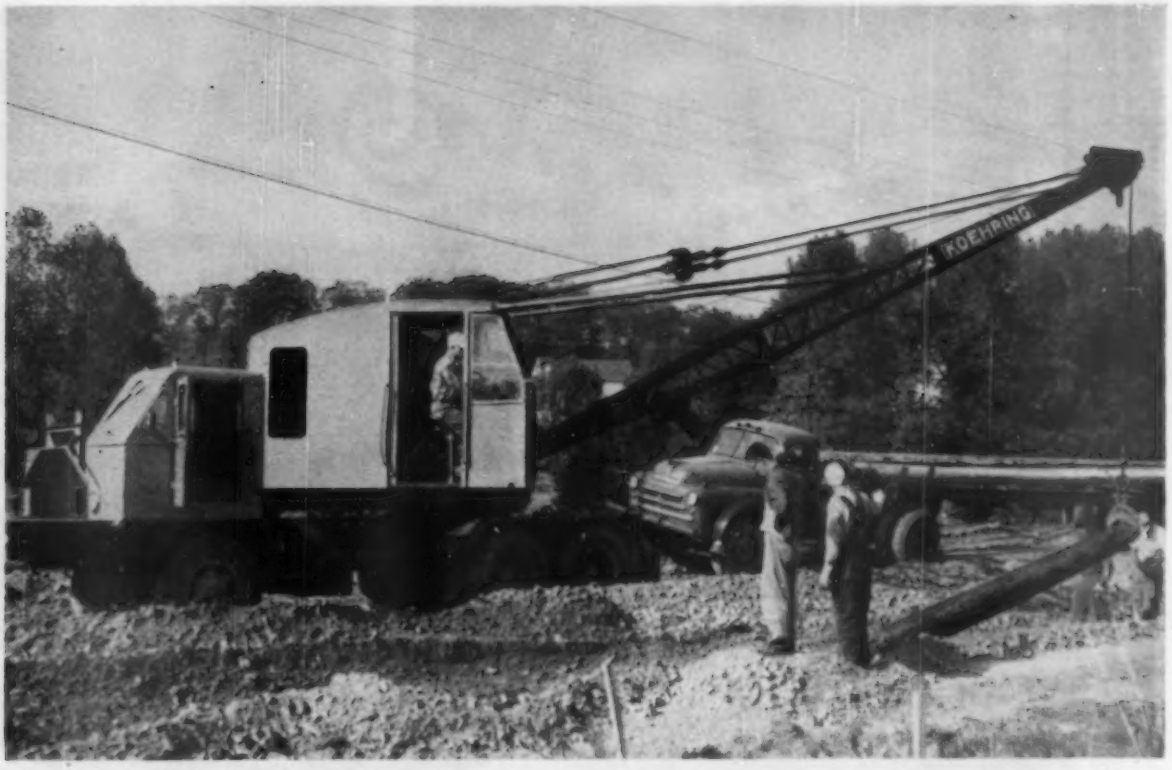

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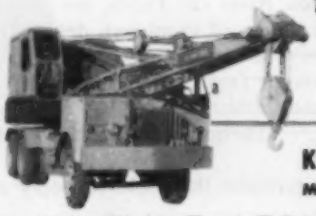

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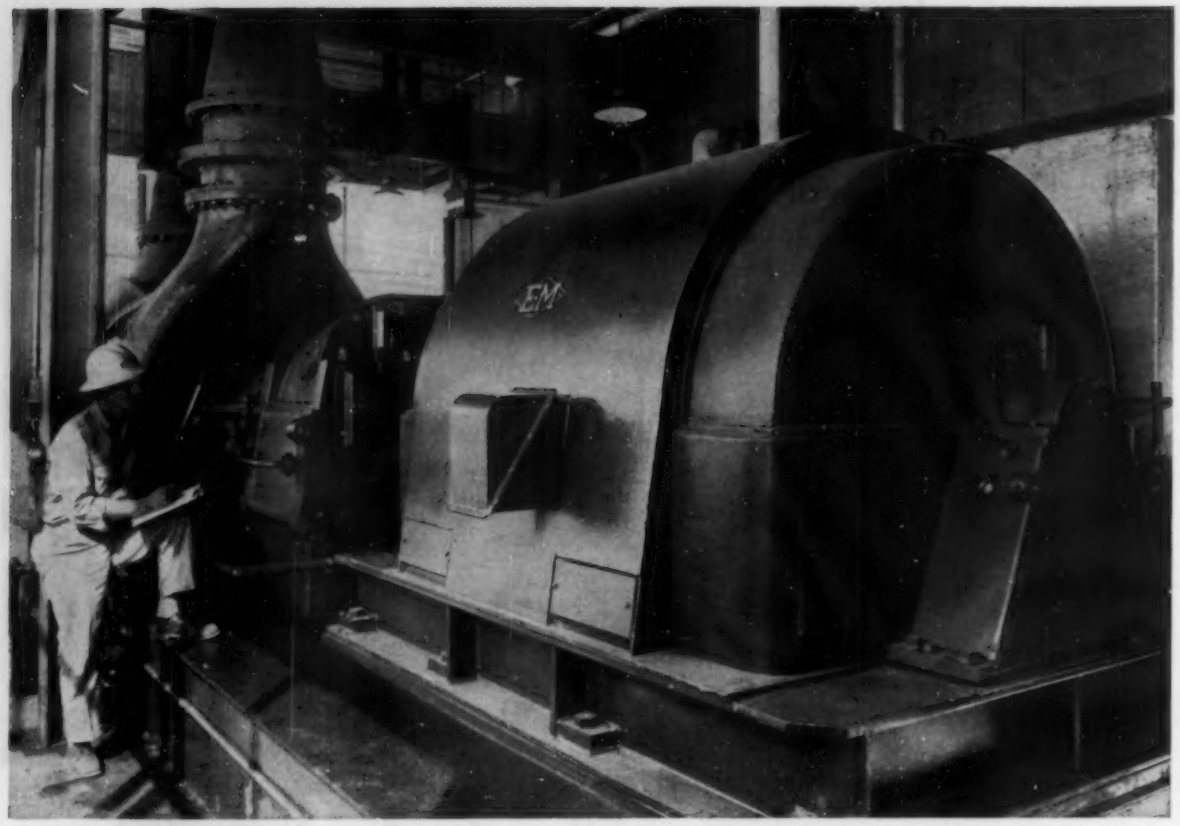

Twin Cities' first refinery uses economical electric motor drive for turbo-blower

At St. Paul Park, Minnesota, a suburb of the Twin Cities of St. Paul and Minneapolis, Northwestern Refining Company is operating the area's first refinery. Originally designed for a capacity of 8,000 barrels a day, the plant capacity is being increased to reach a daily volume of 30,000 barrels.

Located in practical proximity to both Canadian Alberta and Williston Basin Oil Fields, the Northwestern plant is the last word in modern design and operation techniques. The regenerator of the catalytic cracking unit gets its air from a large turbo-blower driven by a compact, efficient E-M Squirrel-Cage Induction Motor . . . 3000 hp, 1780 rpm, 4160 volt, pedestal-type.

This E-M Motor provides three-fold economy on this installation:

1. Electric motor drive has low first cost.
2. No expansion of steam generating facilities necessary.
3. In this installation, electric power costs are lower than the costs of operating a steam plant of equivalent output.

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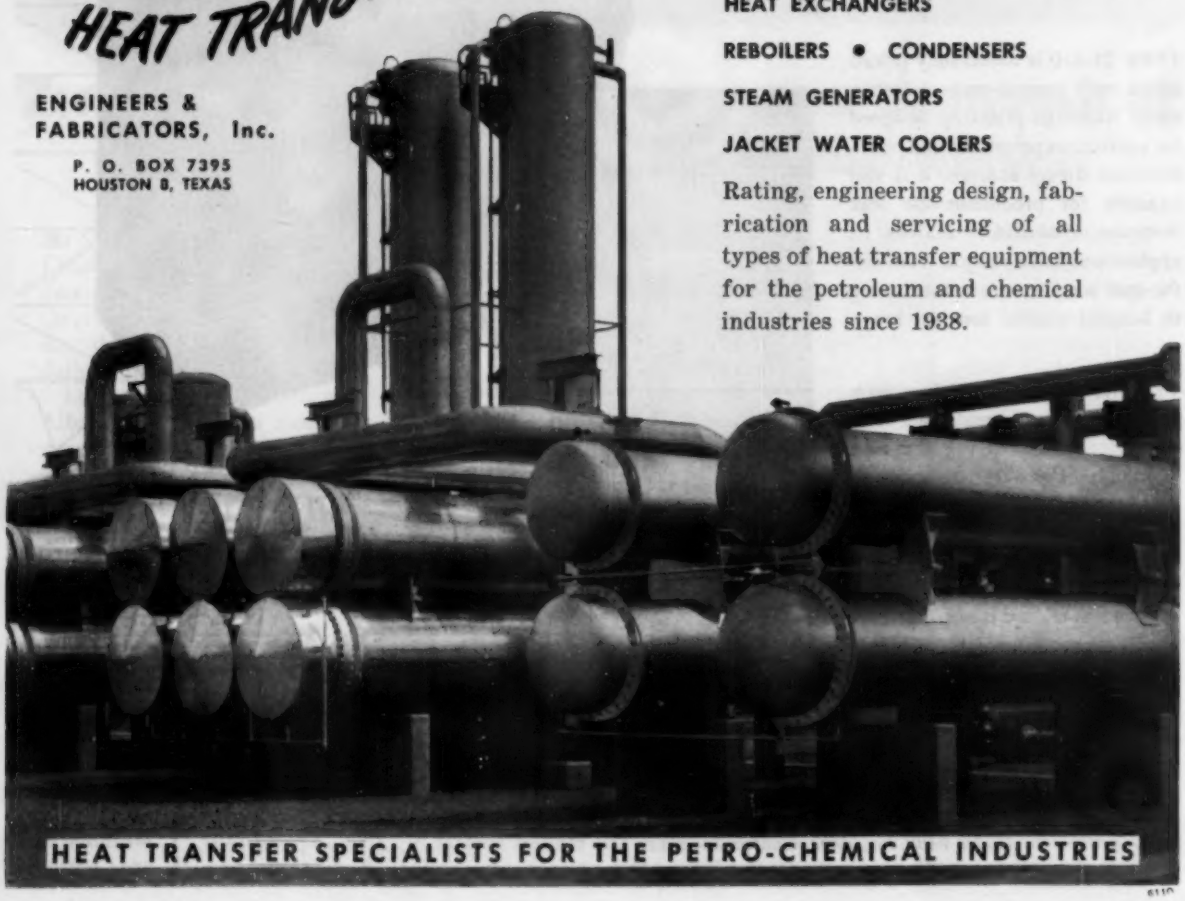

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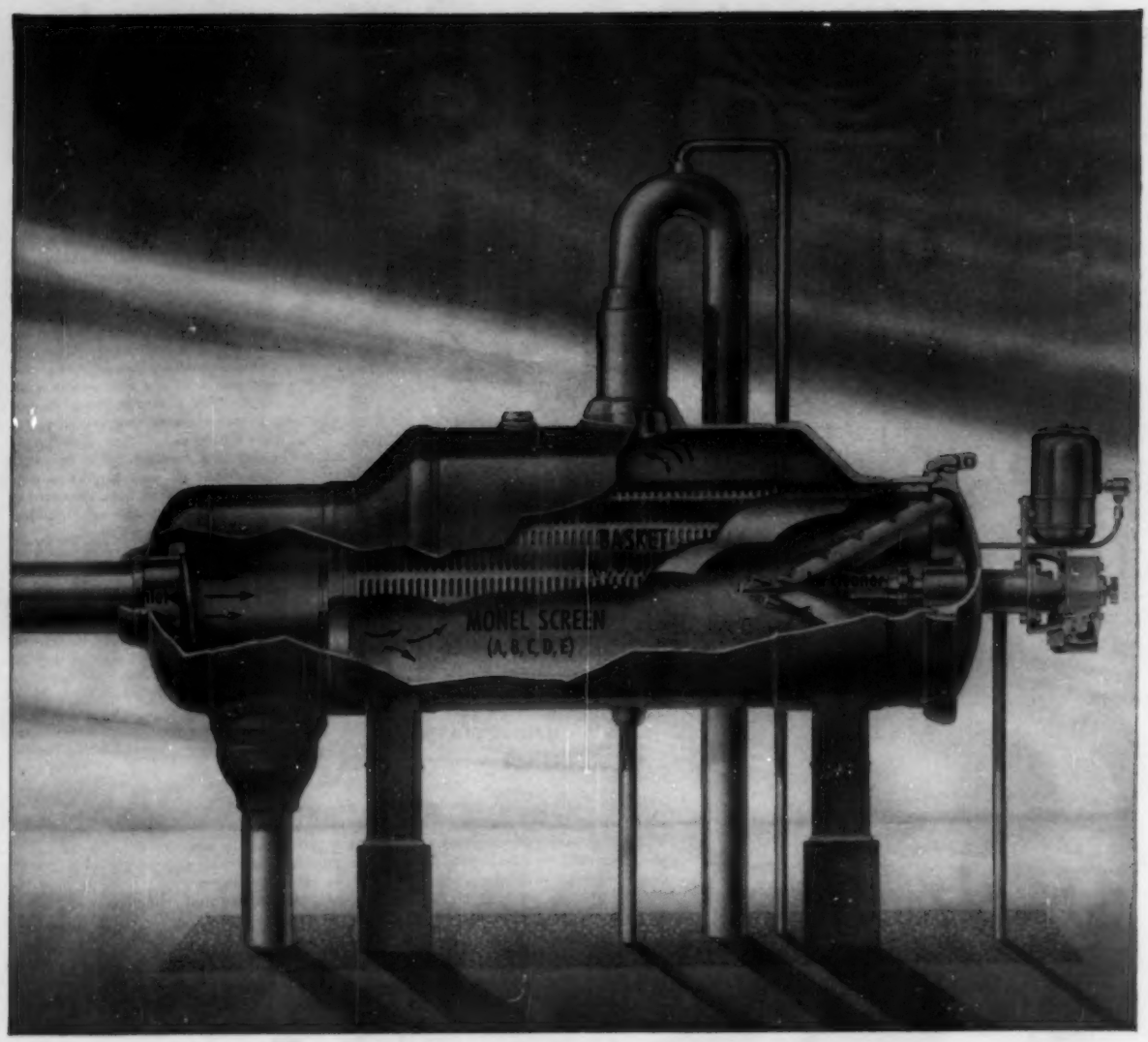

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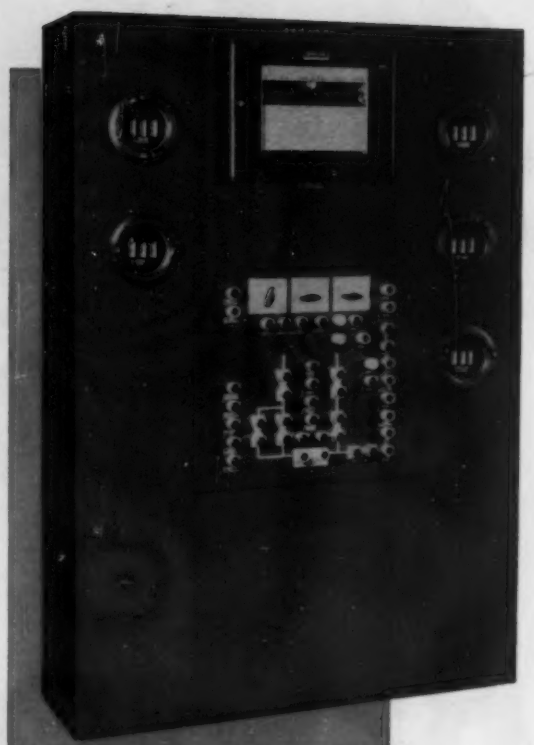

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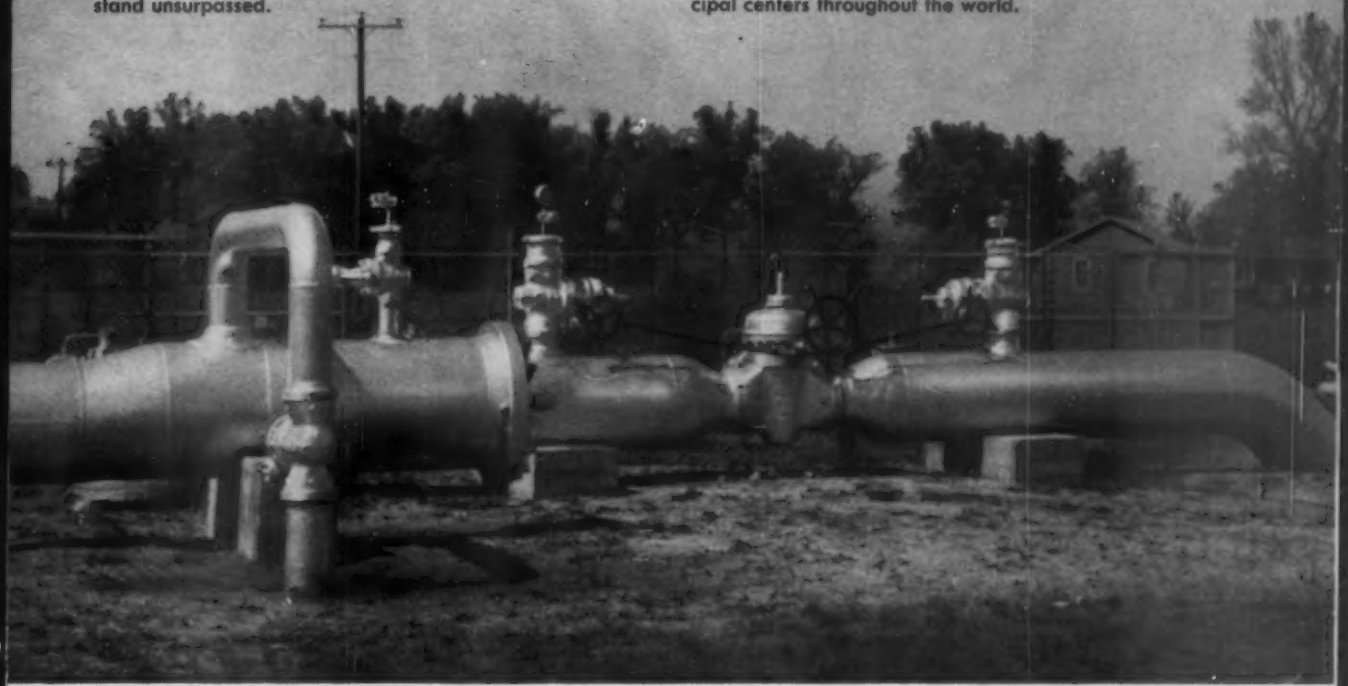

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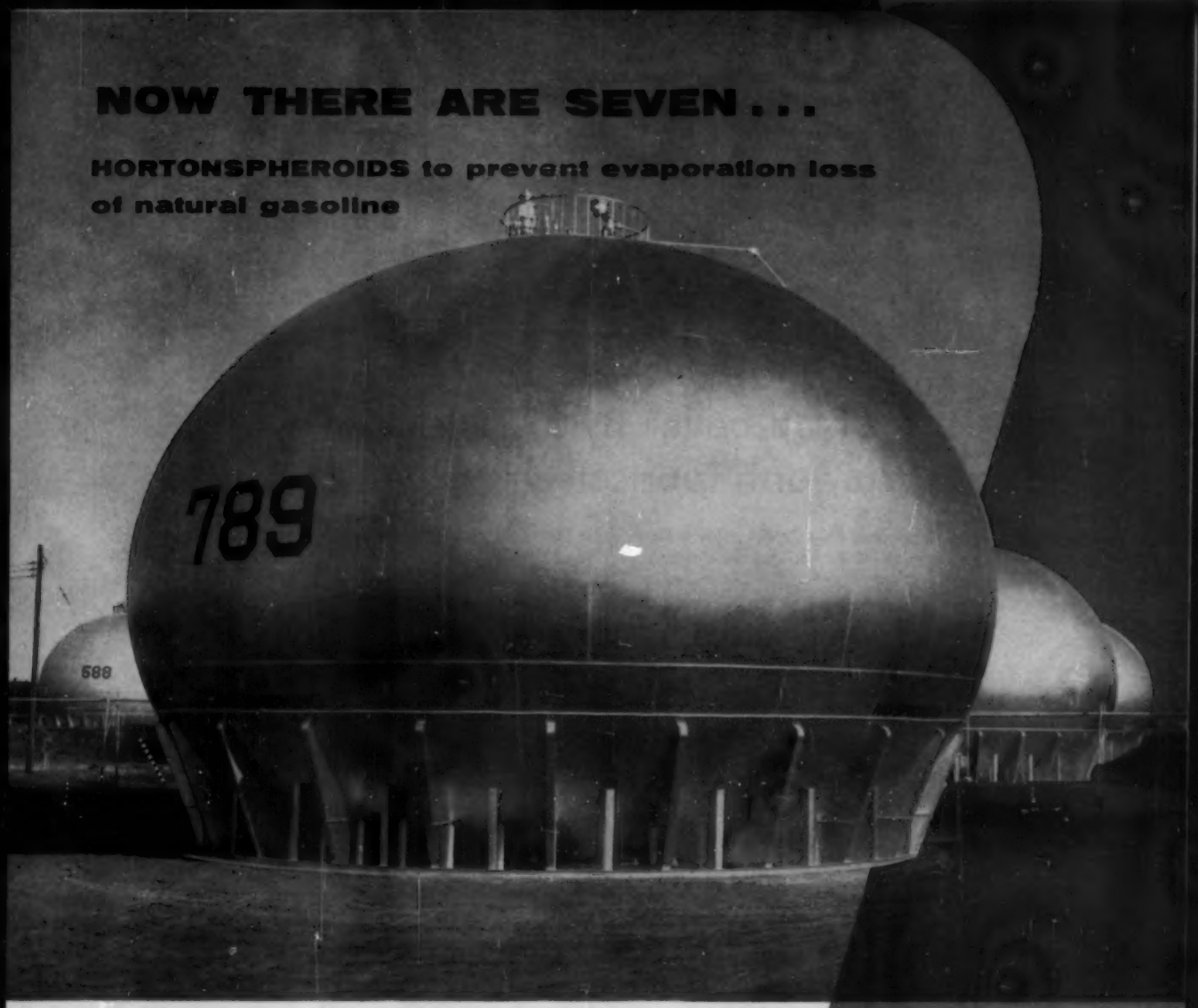

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USS **NATIONAL SEAMLESS PIPE AND TUBES**

UNITED STATES STEEL

The Petroleum ENGINEER June, 1956

BETTER METHODS AND EQUIPMENT

TRAINING AND EDUCATION

IDEAS AND IMAGINATION

BETTER PLANNING, EXECUTION, CONTROL

BETTER ORGANIZATION

BETTER HUMAN RELATIONS

Signposts of Better Management

Why do we work and struggle and plan and save to progress? Why spend all the energy and money to learn better methods? Why study and strain to become more efficient?

The author says we progress or die. Here he goes into the whys and wherefores of efficiency, the means of improving methods, and finally into reasons why business in the United States has become increasingly efficient.

H. H. Hinson

THE economic history of the United States has been one of building newer, more and better things more cheaply. We cannot stand still; we grow or die; we improve or perish. More practically, our ability to do things better increases the standard of living of all of us. This increase in productivity or decrease in unit costs is and should be shared by the consumer, the workers and the people who put their money into business.

The oil industry is presently faced with rising costs, first because of rising costs of labor and the things we buy and, secondly, because oil is becoming more difficult and consequently more costly to find.

The best way to offset these rising costs is to find more efficient and better ways to do things. A company that is not constantly seeking to reduce costs and become more efficient will not perform as well as its competitors and gradually die.

Ways to Increase Efficiency

1. **Training and education**
2. **Better methods and equipment**
3. **Ideas and imagination**
4. **Better planning, execution, control**
5. **Better organization**
6. **Better human relations**

This is taken from Mr. Hinson's speech before the General Session of the 1956 West Texas Oil Lifting Short Course, Texas Technological College, Lubbock, April 19, 1956

TRAINING AND EDUCATION

Training is a very popular word today. The variety of subjects range from human relations to management development and from job training to economics and creative thinking. The methods vary from on-the-job training to college courses.

The most fundamental training is simply training a man for his job. This is a relation between the supervisor and his employee where the supervisor shows the man how to do the job, gives him an opportunity to do the work and then corrects his mistakes until he becomes proficient in his job. More and better training improves efficiency.

BETTER METHODS AND EQUIPMENT

New methods and equipment are usually thought of first when increased productivity or increased efficiency is mentioned. I am sure that everyone here can give specific examples, but I wonder how many fully realize how these new methods and equipment are developed. New methods and equipment are usually developed by the operating men, the engineers, and the scientists; sometimes separately but usually together.

Sometimes the scientist doing pure research finds something new. He may seek the help of the engineer and operating man to find out how the new materials or new principles can be used. Often the new ideas are not exploited until the engineer recognizes that they may be used to solve some problem of the operating man. In this way the engineer serves as a bridge between the operating man and the scientist.

More often new methods and equipment arise from the need of the operator to solve a problem. This method requires an open mind and an inquiring mind on the part of the operator and engineer. Keep asking yourself how things can be done better. Recognizing the problem is half the battle in solving it.

The operator may recognize a problem and solve it without help or he may call on the engineer to provide the answer. The engineer may recognize the problem and solve it alone or with the help of the operator. If a solution requires further research the engineer may pass the idea along to the scientist.

Development of new methods and equipment can be best accomplished by cooperation among the operating man, the engineer, and the scientist; that the equipment salesman is also an important person in the group that promotes new ideas, recognizes problems and serves in taking ideas from the field to the equipment manufacturers.

IDEAS AND IMAGINATION

Probably the most fruitful means of improving operations lies in the realm of ideas and imagination. One good idea applied to your operations can repay your salary many times over. The operating man is fortunate in working at the place where ideas are born.

BETTER PLANNING, EXECUTION, CONTROL

Planning

Efficiency can be greatly improved by planning. Do you plan each day what you are going to do and what each man working for you will do? You have all seen the waste that occurs when a man works only part of a day because his supervisor did not make plans that would keep him busy. Consider not only your men but the most effective use of your available equipment.

Plan your work ahead and then forecast the cost. Try planning and forecasting for a week, then a month, then a year. You will be surprised at the saving and how much easier your work will be.

When you start longer range planning you will automatically consider how you can permanently rearrange your work. In other words you develop new methods and procedures.

Execution

Directing consists of making decisions, communicating the decisions to the parts of the organization where the job is done, and of inspiring the employees with the desire to carry out the decisions and accomplish the objectives.

Snap judgments and one-man decisions should be things of the past. Good decisions are those that are self-evident because the matter has been thoroughly analyzed at each management level as it has worked its way up through an organization structure. Good decisions combine the analysis of the staff expert with the experience of the operating man.

The Author

H. H. Hinson, administrative vice president of Continental Oil Company, was born in Fletcher, Oklahoma, attended high school in Lubbock, Texas, and graduated from Texas Tech with a BS degree in geological engineering and a MS degree in geology.

Before joining Continental Oil Company in 1948 as chief production research engineer at Ponca City, Oklahoma, Hinson spent 11 years in research, engineering and administration for the U. S. Bureau of Mines at Amarillo, Texas. He was promoted to assistant manager of Conoco's production department in 1950, with headquarters in Houston, Texas, and two years later became southwestern regional manager at Fort Worth, Texas. He returned to Houston in 1953, when he was elected vice president in charge of exploration and foreign activities for Continental Oil Company.

The line supervisor should give every possible value to the information of the staff specialist but should not allow the expert opinions to become decisions automatically without checking.

Decisions are valueless until they are communicated to those doing the work. Decisions are often ineffective unless those doing the work have contributed to the information on which they are based and have participated in making those decisions or the objectives back of the decisions.

The best communications are built on knowledge, understanding and confidence. If we err in any direction, it should be in giving too much information. Good communications can be built only over a period of time in which there is a display of mutual confidence and honesty. There is little need to give orders when the people doing the work have a full knowledge of the problem and have participated in working out the solution to it.

A supervisor cannot get people to put forth their best efforts by merely ordering them or exhorting them. Even convincing them intellectually may not be enough. Each supervisor must get acceptance of his orders and create a desire in the people receiving them to do what is required.

Control

Another phase of management that has contributed much to economic success has been the means of collecting information to see that the job is being properly performed and to provide a basis for planning. This function is normally called the control function and is directly related to planning.

Control begins as soon as planning with the

(1) determination of objectives, programs, and profit goals;

(2) determining the procedure of doing the work;

(3) obtaining data on the progress of the work and appraisal of the performance.

One of the best management tools is to determine where progress has deviated from the plans already set up. The cycle of control is completed with the planning function again coming into play by using the information obtained from progress reports.

BETTER ORGANIZATION

The best organization is merely arranging the work to get the job done in the best and simplest way. The organization should be built around the job that is to be done. This

first requires that you know your job, what you are responsible for, and what authority you have to do your job.

You need to know three relations. First, the relation with your supervisor, second, with your employees and, third, with your related coworkers.

Probably the newest concept in organization is that it should be based more on democratic principles. By democracy we mean that more people must be given an opportunity to contribute their knowledge and experience to the solution of a problem on each level of supervision. Decentralization of authority and responsibility seems to be the current trend in many large companies. Some of the objectives of good organization are:

1. *To encourage individual initiative and create a a sense of individual responsibility.*
2. *To define clearly exactly what the man filling a position should do. He must have just as much, no more and no less, responsibility as goes with his task and should have just as much authority as goes with his responsibility.*
3. *To see that each decision is made after full consideration is given to all operating, technical, human, economic and political factors which may bear on the problem.*

Each employee should be given the fullest opportunity to contribute his knowledge and experience. Provision should be made through individual discussions or meetings to work out the best solution possible for each particular problem. These objectives can be accomplished by:

1. *Placing each function or job with the individual or group which has the most knowledge of the matter and the most skill in applying that knowledge.*
2. *Specifying a place for the initiation, direction and control with respect to each function and each level of organization.*
3. *Providing for the flow of enough information upward from the various points of action so that management may measure the progress against the planned objectives and secure information for the preparation of new plans, objectives and policies.*

BETTER HUMAN RELATIONS

One of the best methods of increasing efficiency is in the field of human relations. Perfection in all the other factors can be attained but unless there is some spark to create morale to make the group work together, the group will not reach a high peak of efficiency. Business is just beginning to make progress in this field. These are my ideas of what must be the basic principles in this field.

Christianity and democracy. Probably the keynote of human relations can be expressed in the two words "democracy" and "Christianity". Democracy is a direct growth from our religious concepts. The same factors of democracy and Christianity that made rapid economic progress possible are still the guiding principles for the improvement of business management.

Dependence on people. The idea that business is impersonal is a fiction. In business as elsewhere we deal with our fellow man; we depend upon one another; and we are conscious that men are social creatures, sensitive to consideration of pride, achievement, desire for esteem and affection, and many other drives that have no relation to economics. Likewise, people have a conscience and a sense of justice.

Basic needs. In our feeble efforts to make progress in human relations we have borrowed primarily from the psychologist and sociologists. The psychologist in studying the broad drives which affect behavior has listed these four features:

(1) Sense of dignity
(2) Esteem of others
(3) Instinct for survival
(4) Security

Our quarrel with communism comes primarily with the attitude toward these basic drives or freedom for man to attain them. We feel that man has certain inalienable rights and certain freedoms and that the state must be a servant to man, whereas dictatorships as expressed today in communism make the state all-powerful and the man a slave to the state with no opportunity for realization of his needs. A society which meets these basic needs will flourish whereas one which ignores them must surely perish.

1. Probably the most important element in human relations is the recognition of the inherent *dignity of man.* The first demand is that they be treated as human beings, not like machines. Each of us has a conviction that we have certain basic human rights which others must respect. The sense of dignity is also connected with self-esteem, which is related to the seeking of self-expression, opportunity to advance, success in one's endeavors, and the satisfaction of attaining a useful place in the world.

In respect to human dignity, it is necessary that each worker be put on the best job for which he has aptitude. An effort should be made to assist a worker that has a personality problem, that may be maladjusted, unhapy and inefficient on the job. Procedures should exist that would encourage workers to discuss their grievances and have methods to adjust such differences.

Educational programs may also assist in sustaining their sense of dignity by self-improvement. Unless management itself is infused with an attitude of respect for the dignity of fellow workers, then it becomes extremely difficult to communicate or direct their work.

2. Our need for the *esteem of others* is evidenced by craving recognition and by having confidence that we will be treated like human beings in all relationships. Esteem is related to the opportunity to achieve and create which develops self-assurance and a feeling of real ability.

Self-esteem is founded not only upon an inner conviction of worth, but by recognition of that worth that is given by others. Esteem can be shown when workers are continuously informed about the company's plans and problems, particularly when they are told about the problems in advance and asked their views or possible solutions.

3. In the *instinct for survival,* self-preservation is fundamental in the nature of man. Our concept of the sacredness of human life is derived from our belief in man's spiritual nature as a creation of God. In business it becomes an acceptance of the view that a man needs to earn enough for his family and himself to live as becomes the human being.

4. Probably the most secure place imaginable is in jail, but in attaining that *security* we give up our freedom. In seeking security, our first danger is that we lose our freedom. Real security can come only if we have a growing and prosperous economic system with a high degree of employment. Our record of increasing productivity is a record that also means increased security.

If workers realize that higher productivity is beneficial to them and the whole nation, and if we can keep the elements of our culture that encourage the growth, we can look forward to security and an ever-increasing standard of living for all.

What has made the United States the wonder of the economic world? . . . Business and industry and natural resources are not enough . . . Other nations and other centuries had them . . . The author believes our culture is the basis of our spectacular progress . . .

Basis for U.S. Economic Progress

In order to provide background and perspective for determining the causes and magnitude of our economic progress, I would like first to go back some 300 years to the beginning of our present economic system.

1. Increased Productivity

The past three centuries have witnessed a rate of economic development in the western world which, when measured by any standards we may choose, exceeds any other period of equal length in human history. Probably the only period that approached this increase in productivity was during that dim era when agriculture was invented and the civilization changed from nomadic tribes to an agricultural civilization.

A more surprising trend is the fact that during the last hundred years our productivity is increasing at an even more rapid rate. Although productivity increases vary widely by industries, economists have given these approximate figures:

During the 30-year period, 1850 to 1880, productivity per man hour increased about 1% per year.

The next 30-year period, 1880 to 1910, it increased about 2½% per year.

The next 30-year period, 1910 to 1940, it increased at the rate of 2¾% per year.

During the 10-year period, 1940 to 1950, it increased at the rate of approximately 3.4% per year.

Our standard of living is higher than any other nation's and we are the first nation to essentially banish poverty.

The history of civilization reveals that it is perfectly possible, indeed easy, to dry up the springs of progress in a society and that all past civilizations have eventually done just that.

2. Economic System

Success cannot be attributed to the business or economic institutions alone because we have had trade, business and commerce through untold centuries but never has it flourished as it has today. Previous failures can be attributed to: Arbitrary laws and regulations, taxation, restrictions on people entering business, monopolies granted by governments, or lack of acceptance or participation because of customs or religious practices.

Progress in the U.S. cannot be due to natural resources alone, because many countries have natural resources equal to ours, and many underdeveloped countries have ample resources. So many factors are involved that we must assume that the whole culture affects economic progress.

3. Religious Contribution

If we conclude that culture as a whole is responsible for economic progress, then we must examine the influence of religion because that is the basic element of any culture. Religion sets our pattern of life: Our wants, work habits, our family life, and our code of ethics.

Change. An essential to economic progress is change. In older civilizations, or even in some present-day countries, son lives like father, without change, and so-called traditions or caste systems prevent individuals from becoming anything other than that permitted by the class into which he is born. There is no opportunity for innovation or new ideas. The economy is essentially frozen.

You may ask what this has to do with religion. If we will look back these 300 years, we will see that our country was born during the greatest religious upheaval in history. This was a period of change in that an individual was given the right to worship. Our country was largely populated by refugees seeking religious freedom and change from existing conditions. In other words, their very life was change, and they were willing to leave old countries in order to promote this change.

Individual Responsibility or Initiative. Another concept or individual initiative that is so important to free enterprise. This grows out of the concept that the individual is responsible for his own actions, his own salvation, and his own religious worship. It gave a religicus base to individual responsibility and integrated that individual responsibility into our culture.

Perfectionism. Another religious concept that is important in our free enterprise system is the concept of perfectionism. The religious concepts of perfect love, perfect faith, and a refusal to compromise, has influenced our efforts to develop better or more perfect physical things.

Religious concepts developed in the United States required that the life of a Christian be led in the everyday working world. From this, the concepts of thrift, hard work, sobriety, punctuality, honesty, and fulfillment of promises were made a part of our everyday life.

We take this so much for granted we are not aware that in many countries these same qualities are not a part of the everyday life of their people. These qualities are the same ones that lead to an accumulation of wealth or capital, increased productivity and, therefore, to an escape from poverty.

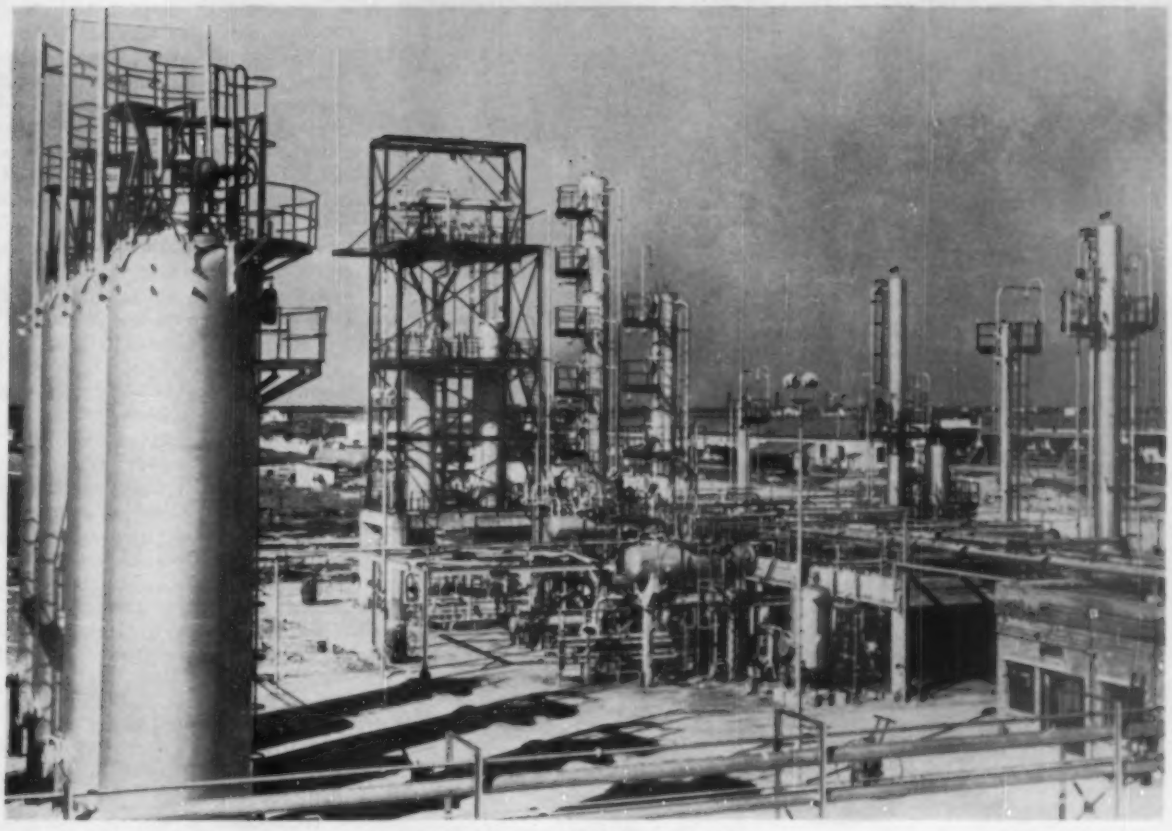
Stewardship and Charity. Another concept of importance in our culture is the concept of stewardship and charity — of giving more than you get. Many countries operate on the theory that there is only a given amount of wealth, and that individuals grow wealthy by taking it away from other individuals. In other words, there is only a fixed amount of wealth, and whoever gains someone else loses.

Our concept is that by adding something, a new idea or a new process, new wealth is created so that everyone is benefited and the individual does not accumulate wealth at the expense of others, but conversely, by developing something new he has actually increased the wealth of other individuals.

System Fails in Other Cultures. This analysis makes it clear why it is so difficult for our methods to succeed in so-called underdeveloped areas and why our program of foreign assistance has been partly unsuccessful. Many of the nations we are helping do not have a culture that is conducive to our type of economic progress. This is also the reason that we often hear statesmen and businessmen proclaim that religion or a revival of religion is so necessary to the preservation of our country or our way of life.

These are some elements and principles that contribute to the success of our country and to our economic system. Each individual must assume a responsibility to know these essentials and to be ever watchful and active to see that we preserve the elements in our culture that encourage progress.

* * *



Catalytic polymerization unit of Porto Marghera refinery in Venice. British Petroleum Photo.

TROUBLES in Italian Oil Operations

Fernando de Mattia

SOMETIME last year, an incident in a small village of southern Italy was reported by Italian newspapers. At Ajo Vecchio, the population was greatly stirred by the sudden appearance of a strange and uncommon phenomenon. Suddenly flames sprung out of the ground, here and there, destroying all they found on their way, haystacks, all vegetation around and even whole farmhouses. One night a peasant was awakened by flames that, rising from under his bed, completely surrounded him. The poor man was terrified and abandoned his home in real terror, assuring every one that he had actually seen hell.

The inhabitants, who could not understand the cause of such flames, forsook the village believing it was possessed by the devil. Only the local parson, with untiring patience and good will, succeeded in restoring confidence.

This recent event, together with many others we could mention, confirms how discoveries of hydrocarbons in Italy are frequent and, we may add, ancient.

As far back as the year 91 B.C. the Roman historian Plinius reported a gas explosion that occurred, at the time, in the Modena Province. The event caused such a stir among the Romans, that, we are told, many Roman patricians were ready to endure the perils of a long and strenuous journey from Rome to Modena, just for the sake of being able to admire the spectacular

EXCLUSIVE

The Author

Fernando de Mattia, doctor of law and advocate, has been connected with the oil industry for 19 years. He spent many years in Libya, Egypt, Ethiopia, Somaliland, and the Middle East. De Mattia, who participated in the fourth World Petroleum Congress as representative of petroleum magazines, writes for Italian and French magazines and an Italian daily. He has published an informative book, *The Wonderful World of Petroleum*, which has been well accepted by technical and daily press.

The small rig that drilled Vallecupa No. 1 in Abruzzo. ENI Photo.

sight of that glowing fountain.

It was only after World War II, however, that researches were intensively carried out by the state and that the nation found the present gas reserves.

Present Italian Oil Areas

The Valle Padana, Abruzzo and Sicily are, for the time being, the only petroleum areas, no appreciable quantities of hydrocarbons having yet been found in other parts of Italy.

Valle Padana. In the Valle Padana, a large set of Mesozoic Tertiary and Cenozoic sediments are to be found. After the discoveries of gas reserves made during the past 10 years, research activities are now concentrated on detailed work of the general survey carried out during the previous year. The gas reserves mentioned above, include the Cortemaggiore one, which produces also a considerable amount of natural gasoline having a high octane number and some LPG.

The Valle Padana, where ENI is the sole operator, has shown, to date, only great gas possibilities. The same may be said of the Delta Padano, where small concerns are operating, with the only difference that no important discovery has been made although about 1000 wells, not exceeding 650 to 1000 ft, have a total daily production of 700,000 cubic meters (about 25,000,000 cu ft) of gas against the 15,000,000 cu m (230,000,000 cu ft) per day produced by the State (ENI).

Abruzzo. It is the opinion of renowned geologists that Abruzzo, one of Italy's most gentle and peaceful districts, the land of olive trees and shepherds, has the most encouraging prospects from the oil point of view. It is even suggested that it may become, some day, the Pennsylvania of the Adriatic Coast. Such an assumption seems to find its confirmation in the recent discoveries of Alanno, Valle Cupa, and Casalbordino.

The story of Alanno began two years ago, when the Gulf Oil and the Montecatini founded the Petrosud, a company for exploring Abruzzo. The Petrosud received permission to explore an area of about 100,000 hectares[1] stretching from the Pescara River valley to the Tronto one. The extensive area presented some encouraging surface signs, which, as one knows, often represent the base on which research is carried out.

As a matter of fact, at the foot of the majestic Maiella mountain group, not far from Alanno, there are asphalt mines having characteristic outflows of natural gas. More than once, peasants digging the ground in search of water sources, were suffocated by poisonous exhalations.

It was in Alanno, one of the many small hamlets of southern Italy, that Petrosud, following accurate geological and geophysic researches, began drilling on the anticlinal of the upper Miocene, which finally discovered the first deposit of Abruzzi. Two wells were drilled, the Cigno No. 1 and the Cigno No. 2, which, at a depth of only 3000 ft, yield a total of 1,500,000 bbl of crude oil per year. Later, all work on these wells was interrupted pending the exploitation concession.

The petroleum strata are of limestone belonging to the middle Miocene-type and crudes obtained have a density of API 39, thus being of a better quality than the Ragusa (Sicily) output, which has a density of only API 19.

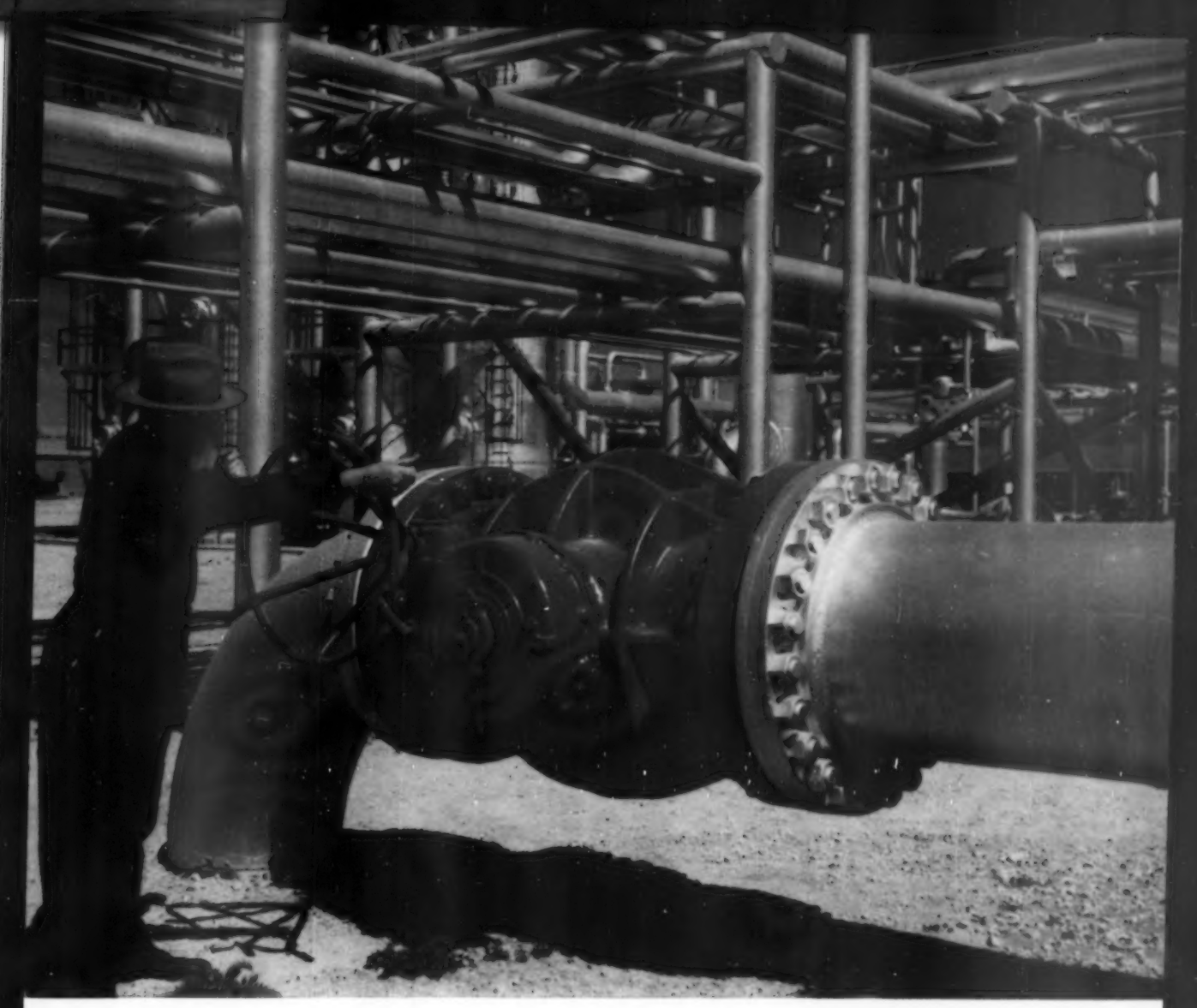
A short time after, at only 1500-meter air distance from Alanno, in a spot called Vallecupa, (from the name of a stream) the Somicen, a company of the ENI group, discovered a new source, which from the first data appeared to be of a considerable importance. The drilling of the area was preceded by accurate geological studies conducted with the help of an helicopter. A small drilling rig was used since detailed studies indicated that oil would be found at a depth of a little over 1640 ft, an assumption that was fully confirmed by facts, oil being actually found at 1690 ft.

Technicians of the state company have stated that crude oil flowed from a 2-in. pipe early on September 16, 1955. From that date to November 10, at least 2000 tons of oil were withdrawn. A pipe line was installed to carry the crude oil to a nearby station.

Drilling operations have continued without any particular difficulty around Alanno. The only handicap is the lack of water, which is very scarce in the whole area. The liquid needed for drilling operations is carried to the spot by tank cars. The oil stratum of Vallecupa has nothing in common with the Alanno one, since it is definitely separated from it by a deep gorge and the rock in which the deposit lies is completely different.

Another successful drilling operation carried out by the State was at Casal-Bordino, 60 km from Vallecupa. Oil in this area, however, was found at a depth of 9938 ft and had a good production. It was drilled with a rotary rig. This discovery is of a special importance since it is the first time that an oil deposit was found in Italy in the middle lower Cretaceous. Such a discovery offers new possibilities in oil exploration. The widespread plan of researches and drilling now being carried out by the State in Abruzzo has already brought discovery of an abundant oil stratum at the foot of Mount Morrone, at a depth of only 787 ft, with a flow of

[1] One hectare = 2.4711 acres.



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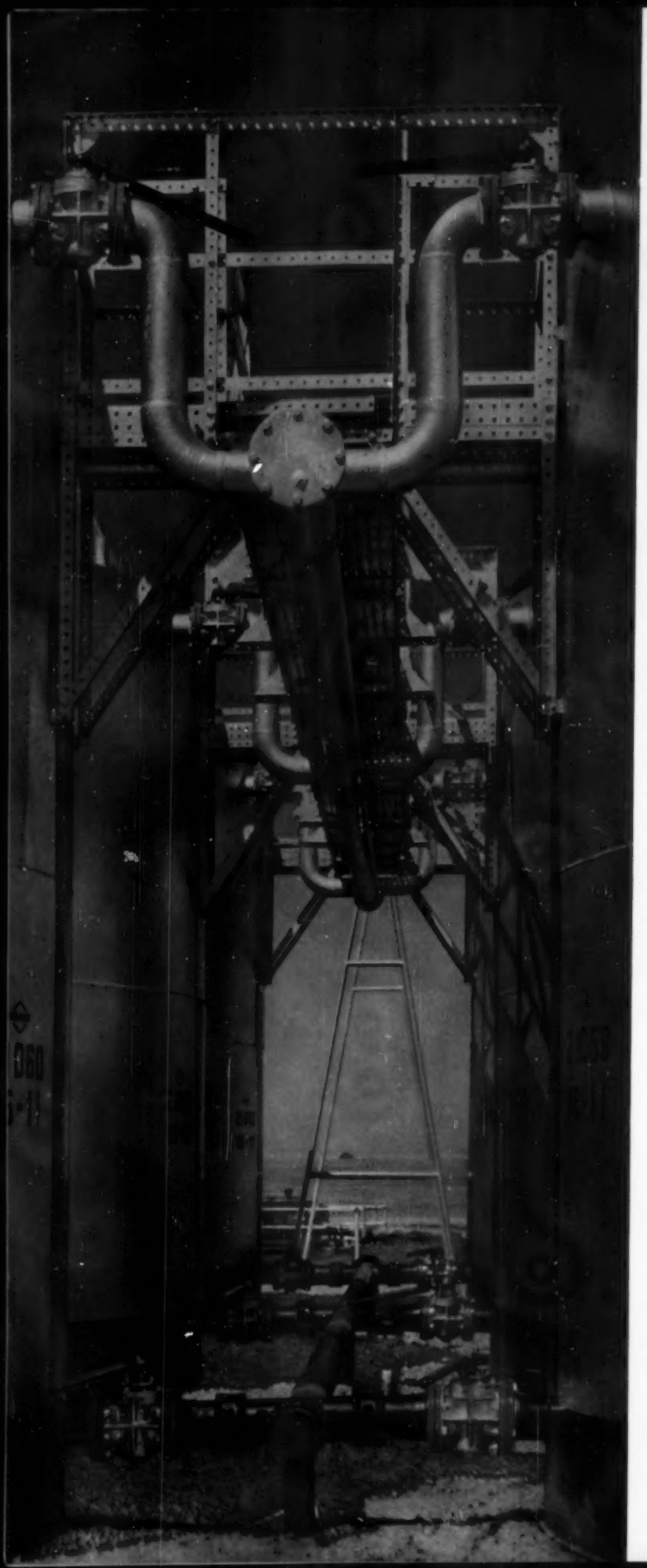

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After long years, Italian prospects for oil and gas development grow brighter but badly needed oil legislation is still in discussion, high taxes cut demand, and refineries have much unused capacity

50 tons every 6 hr. For the time being, this well is called Well No. 26 Tocco.

Sicily. Sicily, one of Italy's most beautiful islands, which the ancients called Trinacria, owing to its triangular shape, has many oil indications. Over 1500 years ago, a Bagdad merchant, Ibn Hawqal, wrote that "fire glows from the rocks of Sicily," and Pliny the Younger described the lake called "Naftia" near Patagonia as a small lake covered by a thin layer of oil substances.

It was a cold and damp night of autumn, October 27, 1953, when the first drop of Sicilian oil came to the surface from a depth of 5886 ft, the drainage was lit up and a very high flame shed its reddish light over the whole village and valley below.

People, believing something dangerous was happening, ran from their houses and Ragusa firemen were on the alert. Those who ran to see what was going on, found the workmen rejoicing around the fire, laughing and touching their foreheads with the liquid, which was flowing from the well. The fire that glowed on the Sicilian rocks had appeared again after centuries.

As far back as 1939, an American geologist, Elmer Thomas, expressed his confidence in the Sicilian oil possibilities, with special reference to the southeastern area. He obtained an exploration license, which was later taken over by Gulf Oil.

The American company conducted geological surveys, which at first covered the whole island and later went into details. There were also stratigraphic and micropaleontological studies and aeromagnetic, gravimetric and seismic surveys before spudding at Pendente, South of Ragusa (later called Ragusa Well No. 1). This well produced the first Sicilian oil.

Discovery of oil — apart from dreams and thoughts of sudden fantastic richness — has already brought beneficial effects to local life, both by reducing unemployment and encouraging house building to meet the increasing demands of the technical staff employed. The discovery at Ragusa has a twofold importance: The discovery of petrol in the Mesozoic limestone and the discovery of a real oil province in the southeast of Sicily.

The eight wells that have been drilled to date all have the same characteristics, both as to the thickness of the productive stratum (about 656 ft) and the pressure, which is so low that pumps are needed. Present production of these eight wells is about 275,000 tons per year, equal to 1,925,000 bbl.

When Well No. 9 was almost completed, it caught fire. Myron Kinley was called to extinguish the fire. This well has a heavier gas flow, which is favorable for future development of the area. The real size of the deposit is not known. The Gulf Company stated that the well has a known reserve of 8,000,000 tons, and a probable one of 15,000,000 tons.

For the time being, no further important discoveries have been made, with the exception of the gas wells in the Catania plain, by the State agencies. An extensive exploration campaign is being carried out by the State, Italian and foreign companies cooperating with it. Difficulties are amazing. There are no rules in Sicily, where, at times, not even the geological period may be exactly determined. The Sicilian region, having realized such handicaps, carried out a set of widespread preliminary researches, supplying very useful information. It is to be hoped that such close cooperation between the Sicilian region, and oil companies may yield favorable results, especially since at least 5 of the 6 million acres that form the island, are believed to be promising oil areas.

Italian Natural Gas

Besides the deposits of crude oil, no doubt of a great industrial interest, natural gas still remains the most important factor in Italy. Gas brought an industrial revolution in the Italian economy, which may be reckoned greater than the one that coal caused in England.

The use of this source of energy has altered the traditional outlook of Italian industry, which till 25 years ago was almost fully dependent on foreign countries for fuel. Italian gas production has been developing at a swift rate, so that, while in 1945-1946 only 12,000,000 cu m were produced, presently the daily production (by the State only) reaches 15,000,000 cu m per day, equal to 22,500 tons of coal.

Consumption of gas is very important (it is expected to reach this year about 3½ billion cubic meters.) Italy has undergone a remarkable evolution as the consumption of gas for thermo-electric purpose has risen from 7 to 14 per cent, while that for chemical purposes has gone from 1 to 7 per cent. The increase will be still greater in the future, after construction of the Ravenna factory, for production of synthetic rubber and chemical fertilizers, is completed.

This plant, which belongs to the ENI group, is in the neighborhood of a gas field, which will be able to supply petrochemicals for rubber and fertilizers. The whole plant will cost $75,000,000.

Closely connected to the gas consumption is the development of gas pipe lines. Laying pipe lines was particularly laborious, owing to the many technical problems, which were rendered more serious by the lack of a legislative ruling.

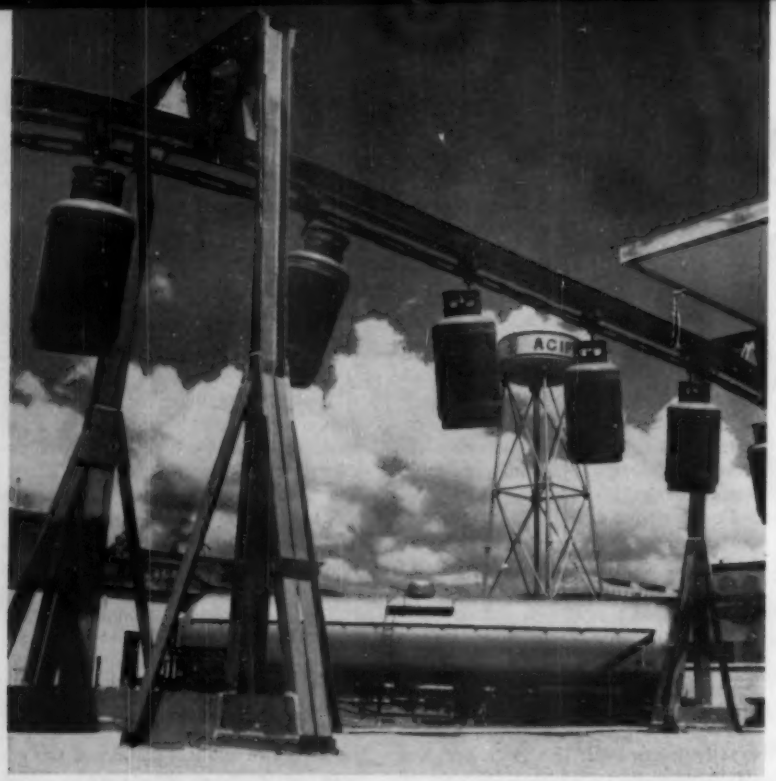
The topographical situation, difficult as it is, was not as bad as the situation in which 8000 contracts had to be made for the installation of the gas pipe line from Cortemaggiore to Turin. Notwithstanding these difficulties, pipe lines run through 4000 km and have become the longest in Europe. The average diameter of the lines has been gradually increased, passing from 96 mm to 250, which makes a daily flow of 20,000,000 tons possible.

It would be impossible to end this report on the State oil activities in the Valle Padana without mentioning the Methanotown (Metanopoli), one of Italy's greatest achievements.

Here grandeur and efficiency of the modern oil town impress the onlooker at first sight. Its wonderful scientific laboratories ought to be visited. They will be the best equipped of the whole of Europe, and they will carry out their activity not only in the technological and chemical fields, but also in the physical one, evolving special researches in the hydrocarbon and petrochemical fields.

After this short parenthesis on Methanotown, a glory of oil industry, we must mention the remarkable development of the use of LPG.

Up to a few years ago, the best known fuel in Italy was coal gas. However, as coal gas production required the building of great distillation units and an expensive transport network, its use was limited to big towns only, so much so that of the 9000 communes of Italy, only 180 were supplied with the so-called "town gas," and at times, even in these towns, living quarters far from the city, were excluded. Such inconveniences were eliminated by the use of LPG, and its development was so quick that last year's consumption



Plant for bottling LPG in Messina, Sicily. ENI Photo.

reached the considerable figure of 250,000 tons, with 5,000,000 consumers. A still greater increase is seen in the future, but it will be easily met by the output of the Cortemaggiore field and of the refineries.

Refining

As mentioned in a previous article,[2] a balance between the actual processing of the Italian refineries, which is of 26,000,000 tons per year, and the utilization of such a capacity has not yet been reached, owing to the limited possibilities of the domestic market and the growing difficulties of exporting finished products. It is even feared, as was recently stated by the Minister of Industry, that the actual exportation level may be maintained.

This difference between the actual process capacity (even higher than what is officially authorized by the government) and the plant utilization has become one of the most delicate problems of the Italian oil industry and consequently of national economy, since 350 billion lire have been invested in this sector.

At present, against crude oil imports of 15,100,000 tons for 1954, exportations for the same period only reached 6,500,000 tons, nor has gasoline consumption increased noticeably owing to the continual increase of taxes that limit the use of fuel and lubricants. All this, points to a rather awkward situation in which only 64 per cent of the refineries capacity was utilized during 1954 (no data are available for 1955) while the percentage of consumption on domestic market only reached about 29 per cent of the output capacity.

No one can foresee how such a problem may be solved in the future, as the only adequate means of doing it, increasing national consumption, is continually frustrated by the increasing taxations of oil products, in particular gasoline and gas oil (taxes reach 71 per cent for gasoline and 67 per cent for gas oil), a fact that naturally has a negative effect on general improvement of motorization.

The only favorable prospective is the opening of new markets for the Italian refining industry through exportation of finished products to such countries as Switzerland, Greece and Spain, which do not have an activity of their own in such a field.

Conclusions

The Italian energy consumption (calculated in tons of coal at 7500 calories) was in 1954 about 43 million tons, with an increase of 70 per cent compared to pre-war figures. This favorable development of energy consumption shows the considerable effort made by Italian economy in order to solve its problems. The national income, during these last 5 years, has visibly improved, notwithstanding the increase of population and rise of the cost of living. Even so, for each unit of fuel consumed by an Italian, a Frenchman consumes 3, a German 5, an Englishman 7 and an American 13. It is obvious that still more has to be done to better the living conditions of the Italian people and bring them on a level with other European people.

In order to reach such an objective, a plan known in Italy as "Piano Vanoni" has been prepared. It has the twofold purposes of solving the unemployment situation by creating 4 million new jobs, and of raising national income over 60 per cent within the next 10 years. The basic factor of such a plan is a proportionate increase in energy consumption, which in 1958, should reach 58 million tons (always reckoned in equivalent tons of pit-coal). Demands of energy should be met as follows:

34 per cent from electric energy for a quantity of 20 million tons.
13 per cent from natural gas for a quantity of 8 million tons,
34 per cent from oil products for a quantity of 20 million tons.
17 per cent from coal for a quantity of 10 million tons.

Limiting our analysis to the energy sources represented by petroleum we believe that 8,000,000 tons of natural gas (equivalent to 5.3 billion cubic meters) can be easily produced (actually the production is already of 3.5 billion cubic meters per year), owing to our gas reserves, which according to data in our possession, amount to 150 billion cubic meters.

As to the oil problem it is still far from being solved. In 1954, Italy imported 15,100,000 tons of crude oil.

Dr. Mattia will write soon on Italian and Sicilian petroleum laws.

Present Italian oil production cannot be considered definitely since the deposits in Abruzzo are not yet determined.

It may be, however, roughly valued about 1,000,000 tons, taking into consideration the deposits of Cortemaggiore, Ragusa, Alanno, Vallecupa, etc., which means that Italy will have to import in the future 19,000,000 tons of crude oil in order to meet the country's requirements of liquid fuel.

The situation will be completely different should local production reach the point of meeting all national requirements, a possibility which appears to be possible. Herein lie great hopes for a better and more prosperous future for the Italian people. * * *

[2] The Petroleum Engineer, May, 1954, "Italian Refining Capacity Outpaces Demand—Fernando de Mattia.

Sixth of a series

Communication:

Puff puff Dear mumble mumble In answer to your cough cough etc. . . .

Don't mumble or chew your words.

Twelve Tips on How To Dictate a Letter

Dennis Murphy*

What Kind of Boss Are You?

All kinds of bosses are letter dictators:
Mumblers, and walkers, and window gazers,
Jinglers of money, and tobacco chewers,
Deleters who cut, and chronic stewers.
So the first thing you need to dictate a letter
Is a lovely gal who looks good in a sweater —
She can follow ideas, known and unknown,
Much better than any old dictaphone . . .

This is the beginning of some doggerel that burlesques a wolfish boss and his glamorous secretary. But a recent survey shows that most American businessmen today prefer a secretary who shows **initiative** in her work, the ability to type quickly and accurately, the ability to file and find information speedily, a winning telephone manner, punctuality, and personal neatness. Instead of ravishing beauty and disturbing sex appeal, most bosses prefer somebody who can "manage the office" while they are away.

The Correspondence Team

Some managers write their letters in longhand rather than dictate, even when a good secretary is available. Often they feel self-conscious or fear they can't dictate intricate material very well. They need this training and practice, however, because any great quantity of written communication—memos, letters, and reports — is nearly always the result of teamwork.

Any correspondence team can achieve cooperation if the boss trains his steno-secretary fully and if she tries to reproduce his thoughts faithfully. Each must understand the work of the other. Don't waste time to dictate anything that is already printed, typed, or handwritten. And don't dictate faster than about 80 to 100 words a minute until your helper gets used to your manner; an even dictation that is clearly understood is always better than spurts at break-neck speed.

Twelve Tips

1. **Plan a regular dictation period.** Early morning usually affords freshness and few interruptions, but emergency dictations may bob up any time. A poor boss will dawdle away the entire day, call his stenographer 30 min before quitting time, dictate a day's typing, and expect her to finish it that day. Are **you** that kind of thoughtless boss?

2. **Read your first-class mail carefully.** Work as a team with your stenographer. Train her to open, read, sort, and stamp your mail and to answer routine letters.

3. **Tackle your most urgent letters first.** But if an important decision must be made, consult the proper sources, sleep over it, and take time to word it right.

*Administrative Assistant, Service Pipe Line Company, Tulsa, Oklahoma

Type those up and get them out this evening, Miss Smith.

Plan a dictation period—don't leave it to the last minute.

4. **Pencil notations on the letter you receive.** Indicate roughly your main points and number them in the order you plan to answer them. Get all your facts ready.

5. **Never repeat, word for word, the letter you receive.** This needless repetition is the biggest farce in the art of dictation! Identify the letter accurately by date, file number, or subject. Here are two good opening sentences that immediately help to set up your purpose: "Thank you for your letter of March 12 asking about the quarterly report." "Please refer to your letter of September 15 concerning the API meeting." *Re:* and *In re:* are old-fashioned. But never get into such a rut that all your letters sound alike; try to personalize each one.

6. **Set up your purpose** in the first paragraph. Make it brief. Develop each point in a later one. Cultivate a method in your work that will put your helper at ease.

7. **Dictate in your natural speaking voice.** Enunciate carefully and clearly. Keep an even speed, and talk as though your addressee were seated across from you.

8. **Avoid personal peculiarities.** Don't mumble or chew on your words, stroll around the office, gaze out of the window, jingle money or keys, or let your sentences fade away inaudibly — and expect any helper to come up with accurate copy. Don't dictate with gum, a pipe, cigar, or cigarette in your mouth. If you have whistling dentures or body odor or halitosis — do something about it!

9. **Help your stenographer-secretary** by pointing out unusual spellings, punctuation marks, quotations, underlining, spacing, and the like. Train her to search for the best forms of composition, and cooperate with her toward perfection. Thank Heaven if your helper is intelligent, resourceful, and accurate — but praise her!

10. **Equip yourself** with a knowledge of grammar, word usage, and sentence structure. Otherwise, how will you know whether your helper is doing her job correctly?

Tut tut, Miss Smith, if it's too fast just say so.

Enunciate carefully and clearly—keep an even speed.

11. **Listen carefully** when she reads your dictation back to you. **Train your ear** to catch redundancies, repetitions, jerky cadences, harsh sounds, and awkward phrases. Teach her to do the same. Give her authority to improve your writing without changing the content and meaning.

12. **Read her typewritten copy carefully before you sign it.** Glaring errors often show up in this final check. If this copy isn't exactly as you desire it, make the necessary revisions. Then courteously ask her to retype your letter. Aim to get everything right the first time, for you are the one who is finally responsible. So, always read before you sign.

Please Take a Memo!

To simplify intracompany communication, try to keep all of your writing at a minimum. You can pen or pencil a note to one other person, but you'll need to dictate a memorandum if two or more readers are concerned. Be sure that all the persons involved get a copy. And, train your steno-secretary to *date every memo.*

The first thing any reader wants to know when he picks up your memo on his desk is: What is it? Who sent it? Why?

Talk as though your addressee were seated across from you.

1. **Let your reader know at once what it's about.** A descriptive title will help.

2. **Use subtitles** if your memo runs to several paragraphs.

3. **Highlight the essentials** by placing them first, by numbering each item, and by underlining key words.

4. **Keep your memo brief.** The shorter it is, the better are its chances of being read. You can shorten your memo by half if you use an outline style, shrink your sentences, and cut out repetitions. Don't let your memo run over one page. Half a page is better. Once your office helper understands this routine, she can type your memos in a jiffy.

Summary

1. **Dictate with simple words.** One or two long words (of three or more syllables) are enough in a sentence.

2. **Dictate with short sentences.** Hold the average to 20 words or under.

3. **Dictate with regular phrases.** Pause at the end / of a complete unit of thought / before going on to another unit.

4. **Dictate for brief paragraphs.** They are easier and more restful for tired eyes to read.

5. **Train your steno-secretary** to "run your office" smoothly while you are gone. ★ ★ ★

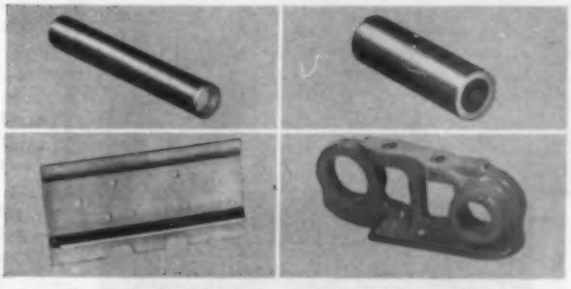
When it comes to parts, don't let "look-alike" substitutes get you off the track.

Genuine Caterpillar track shoes are made of only high-quality rolled steel, specially hardened by an exclusive process. Links are induction-hardened, pretested steel, and their design is the result of years of research and development. CAT* track pins and bushings are also specially hardened, with a deep case and a tough core. You're *sure* you're on the right track with Cat original parts.

With substitute parts, can you be sure of anything?

Better see your Caterpillar Dealer's Parts Representative — and get Cat original parts every time.

Caterpillar Tractor Co., Peoria, Illinois, U. S. A.



Caterpillar track parts take the brunt of the punishment when the going is toughest. They are subjected to abrasive sand and gravel, brutal shock loads from stumps and rocks. Why take chances with substitutes?

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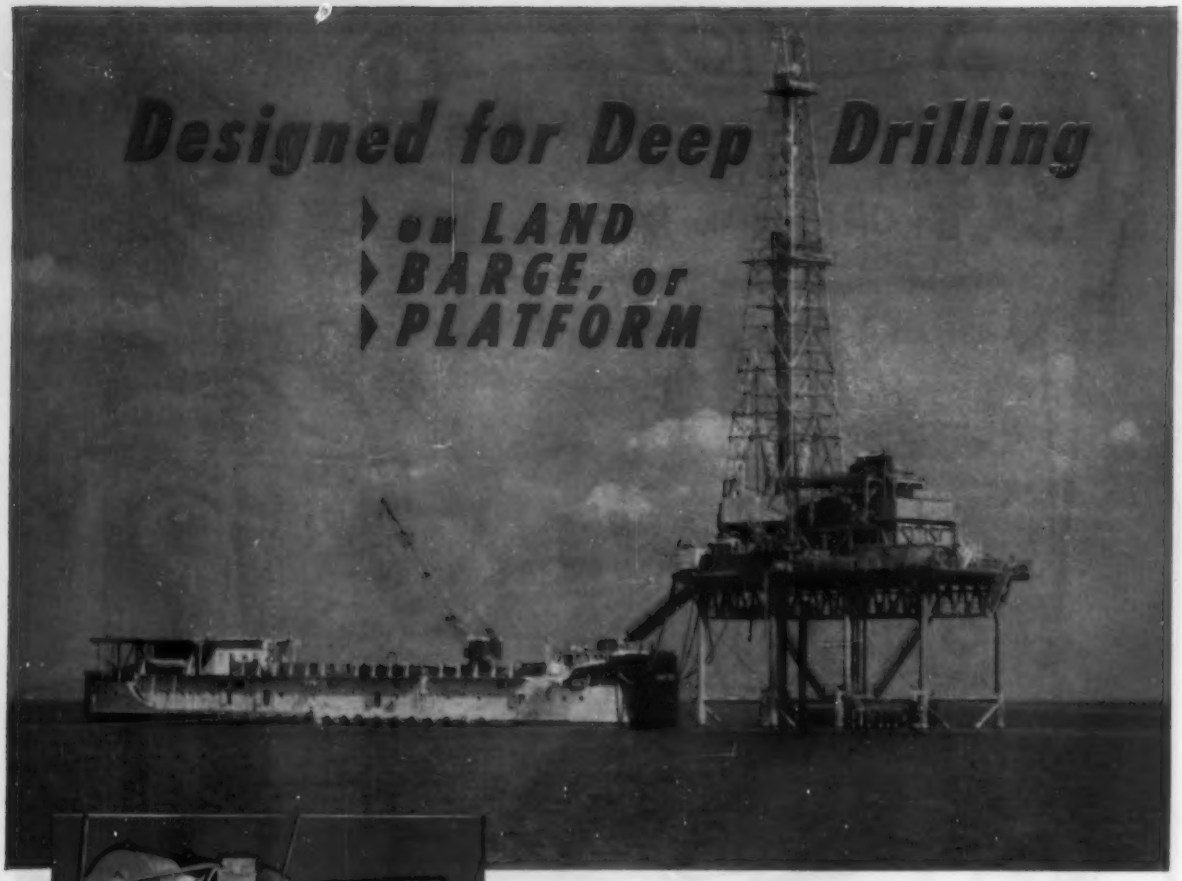

- Adjusting linkage and exposed gearwork protected against corrosion by special plating.
- Sectional construction facilitates transportation.
- Six hoisting and three rotary speeds.
- Two 42-inch VC 1200 Fawick Vantorque clutches on drum shaft.
- Carbontherm hydromatic brake or Dynamatic brake on extended drum shaft.
- 32½" x 57" drum, with 50" x 18" water circulating brake rims.
- Casing spool package, friction clutch controlled, optional.
- An all-electric rig—drawworks can be furnished with friction or jaw clutches.

M-D56-2

Unit Rig U-1220* Drawworks

The Model U-1220 was developed specifically for deep drilling. It meets all requirements for extreme depths, portability and endurance—regardless of location.

The rig shown above drilling in the open Gulf is equipped with a Unit Rig Model U-1220 drawworks, and a 3-engine rig drive. The drilling barge tender carries 3 Emsco D-700 slush pumps, powered through an LS1420 Unit Rig 3-engine, 3-pump drive compound by 3 PTDS-8 Superior diesel engines.

All major drilling equipment was furnished by Mid-Continent Supply Company.

*** Indicates 1200-2000 input horsepower.**

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One of the big problems of our times is the question of how to help promising students get an education . . . . Here is one answer to the question that is suitable for many companies, both large and small

You, Too, Can Give Help to Education

BUSINESS firms looking for a way to give financial aid to our colleges and universities should become acquainted with the well conceived program of the National Merit Scholarship Corporation.

This program, worked out after more than 3 years of consultation with leaders in education and industry, has the hearty endorsement of both.

What It Is

The National Merit Scholarship Corporation is an independent agency set up for the purpose of finding each year high school seniors throughout the nation most able to benefit from a college education, and then providing these oustanding young people with a chance to go to college.

The corporation was financed initially by foundation grants totaling $20,500,000 to cover a 10-year period. The initial financing enables NMSC to carry out its technical and administrative functions involved in setting up a nationwide pool of winners and allows for a continuing basic program of National Merit Scholarships.

The National Merit Scholarship Corporation not only finances the total cost of a thorough nationwide talent search but has offered to devote $8,000,000 to match, dollar for dollar, gifts by business firms for merit scholarships and supplemental gifts to the institutions where the scholarships are used. Merit scholarships financed by business firms will bear their own names.

The National Merit Scholarship Corporation earnestly invites joint participation by business and industry in order to provide opportunity to the maximum number of students, and to give needed financial help to the colleges and universities these students attend.

*Taken from a memorandum of the Education Department, National Association of Manufacturers, 2 East 48th Street, New York 17, New York.

What the Program Is Designed to Do

Reliable figures show that half of the nation's top ranking high school graduates do not go on to college. One of the chief causes for this immense waste of our best young brain power is a lack of money.

At the same time our colleges and universities are hard pressed to maintain their present status and are in need of financial help.

Meanwhile many members of the American business community, aware of their responsibilities and their own long-range self interest, are investigating ways and means to help both students and colleges.

The Merit Scholarship Program is designed to get as many as possible of the best high school graduates into and through college and avoid the duplication and waste involved in many different selection programs.

The National Merit Scholarship Corporation spends funds to the limit available in direct support for hundreds of Merit Scholars. It also helps outstanding students, who could not be included in the basic scholarship program, by having their qualifications circulated among other scholarship granting agencies and institutions, increasing the chances for financial help.

The thousands of fine youngsters who participate in the program at one stage or other come to think of college as the next logical step in their careers. And many younger high school students will aim to become Merit Scholars, stimulating at all levels of high school an interest in college education.

Three Basic Elements

The National Merit Scholarship program is built on three essential elements. These are:

1. A yearly nationwide talent search to seek out those high school seniors anywhere in the United States who are most able to benefit from a college education.
2. Providing for these deserving young people the financial help they need to see them through four years of college.
3. Giving to the accredited colleges selected by the Merit Scholars, funds to meet the full cost of their instruction.

How the Talent Search Works

Principals of every high school in the United States — public or private — are each year invited to name the five per cent of their respective senior classes best suited to compete for Merit Scholarships. This year more than 11,000 high schools participated in the program and 60,000 outstanding seniors took the initial test.

The higher ranking of these — approximately one in ten — subsequently is asked to take a second examination.

Top students on the second test are then carefully screened by means of their own written reports, reports from school officials, and their school achievement records.

Finally, Merit Scholars are selected to the limit of available funds.

The cost of all examinations administered in the talent search is borne entirely by National Merit Scholarship Corporation. Neither students nor participating corporations pay anything for any part of the nationwide talent search.

How Much for Each Student

The amount of financial support accompanying a Merit Scholarship is based on financial need. Each student's needs will be checked with parents and college. Aid will range from an honorary $100 per year for students able to provide their own tuition and expenses — to grants of full tuition plus living expenses for four full years of college.

"The 'poor boy makes good' saga has become an American cliche. Yet many a poor boy who might have made good with the proper training never had that training. His brains and ability were lost. The National Merit Scholarship Corporation contrives to protect society — you and me — against such loss. And it protects business and capitalism, too."[1]

How Colleges Are Helped

Students participating in the Merit Scholarship Program may choose to attend any accredited college or university in the United States. An institution where a Merit Scholar attends will receive, over and above the student's tuition, a supplemental grant equal to the full amount of tuition, providing the grant plus tuition does not exceed $1500 per year.

Even in cases where Merit Scholars are receiving only the honorary $100 per year from the corporation, the colleges they attend will get the full supplemental grant.

Advantages of Participating

Corporations participating in the Merit Scholar program have the satisfaction of knowing that every dollar they give will go to a worthy Merit Scholar, and to ease the financial problems of the college he is attending.

The Merit Scholar Program is setting a pattern of efficient, businesslike administration of financial aid to students and institutions alike, a pattern of great importance in the future of American education.

Participating firms are building for themselves and their business colleagues an increasing pool of valuable, specially trained personnel upon whom the future welfare of the American economy will be based. In the words of J. A. Livingston, "The mind is the new economic frontier."

Sponsors of Merit Scholars retain full identity and credit within the framework of the program and at every step in the program.

A participating firm may specify that its scholarships carry its firm name or the name of someone the firm wishes to honor.

A participating firm is invited to prepare literature telling about its own scholarships. This literature will be distributed to all the thousands of schools participating in the Merit Scholar talent search.

All payments made to Merit Scholars or to colleges and universities will be made in the name of the participating firm, and Merit Scholars will be identified by the designation selected by their sponsors. It is the Smith Company Merit Scholarship Program, the Smith Company Merit Scholar, the Smith Company educational supplement to the college, and the Smith Company payment to the scholar. Scholarships provided by matching funds or the basic sustaining program will be called National Merit Scholarships.

By joining with the National Merit Scholarship Corporation, corporations can avoid needless — and often prohibitively expensive-duplication in the process of finding the best possible scholars.

How Businesses Participate

Business concerns participate in the Merit Scholar Program from year to year on the basis of an agreement between each firm and the National Merit Scholarship Corporation. As all Merit Scholarships cover the four years of college, participation naturally covers a commitment to see the selected group through their college, provided they maintain acceptable scholastic records.

Corporations are free to decide how many Merit Scholars they wish to support, and to name conditions of selection which the National Merit Scholarship Corporation will fulfill within the wide latitude allowed by the nature of the program.

Merit Scholarships, including the supplemental grant to institutions, will average about $1500 per year each, or $6000 for the four college years.

A participating corporation may specify several kinds of conditions for the giving of Merit Scholarships which it sponsors. One company may wish to limit its awards to engineering students. Another may specify that winners be limited to its natural marketing area. Other firms might be interested in certain colleges, or certain types of colleges.

The program is capable of considerable adaptation so that almost all conditions can be met.

A number of leading companies in the American business community have already joined the Merit Scholar Program and more than 400 scholarships will assuredly be given in the coming year. Presently participating firms include Sears-Roebuck Foundation; Time, Inc.; McGraw-Hill Publishing Company; Stewart-Warner Corporation; Pittsburgh Plate Glass Company; Johnson Motor Lines, Inc.; Gillette Company; General Foods.

Newspapers and other communications media have given the program broad coverage and high praise. The Chicago Daily News made this comment: "It is as commendable for the wisdom of its provisions as it is remarkable for its scope."

The Christian Science Monitor said: "Efforts of this magnitude might set up the momentum necessary to get alternatives to government subsidy of colleges on an enduring footing."

There are more advantages in the Merit Scholar Program—for students, colleges, and for corporations — than can be told in this brief description.

More information about any aspect of the Merit Scholar Program, including details about how your company can join this program, may be readily obtained from John M. Stalnaker, president, National Merit Scholarship Corporation, 1580 Sherman Avenue, Evanston, Illinois.

"The National Merit Scholarship Corporation... is part of a growing pattern of private aid to education which is an answer to those who believe that only the Federal Government is capable of settling the problems." — Wall Street Journal, September 8, 1955. ★ ★

[1] J. A. Livingston, Washington Post & Times-Herald, September 17, 1955.

Ways to Solve Engineer Shortage

"The Soviet Union has reached technological maturity . . . in a big hurry," William Weitzen, a deputy United States Air Force secretary, told a meeting of the American Institute of Electrical Engineers last month. "One devastating example proves this point — in 1946, our experts thought Russia couldn't produce an atomic bomb in less than six to 10 years, if at all.

"They did this job in about three years."

To alleviate what Weitzen called "the nation's dearth of engineers and scientists . . . on an increasingly alarming scale," he suggested:

1. Attacking the first and foremost problem, teaching itself — especially science subjects. Making it more attractive as a vocation at both high school and college levels.
2. How about increased financial support by industry of scholarships in the sciences? And increased salaries and opportunities for present technically trained personnel?
3. Why don't we have more women engineers and scientists? Although there are three men graduates for each girl, the ratio in engineering is 500-to-1.

HOUSTON NATURAL GAS CORPORATION ODEM FIELD COMPRESSOR STATION—equipped with two Beaird-Ingersoll-Rand 660 h.p. 12SVG four cycle gas engine driven compressors, Young radiators, lubricating oil coolers and gas coolers, and all necessary controls. Other sizes 110 to 660 h.p.

Quick Installation –

PACKAGED COMPRESSORS SUPPLY NEEDED RESERVES

Houston Natural Gas Corporation built this compressor station in Odem Field, Texas, to boost natural gas to lines serving the expanding Corpus Christi area. Equipped with two 660 h.p. Beaird-Ingersoll-Rand 12SVG packaged units, it is capable of handling 12 mmcfd. Utilizing packaged compressors minimized field assembly and added needed reserves at a saving in both time and cost of installation.

Operating with two stages of compression, the units pick up gas from nearby wells at 50 psig. and boost it to the line at 325 psig. Automatic controls built into the compressors prevent suction pressures from being pulled below 50 psig. required for efficient operation of the separators. Flexible in design, the units can be converted to three-stage compression to follow the pressure on down as the field grows older. When reserves are depleted the compressors can be moved to other service and nearly all of the present installation salvaged for re-use at the new location.

Let us show you how complete packaging simplifies installation and reduces field assembly costs.

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PACKAGED COMPRESSOR PLANTS

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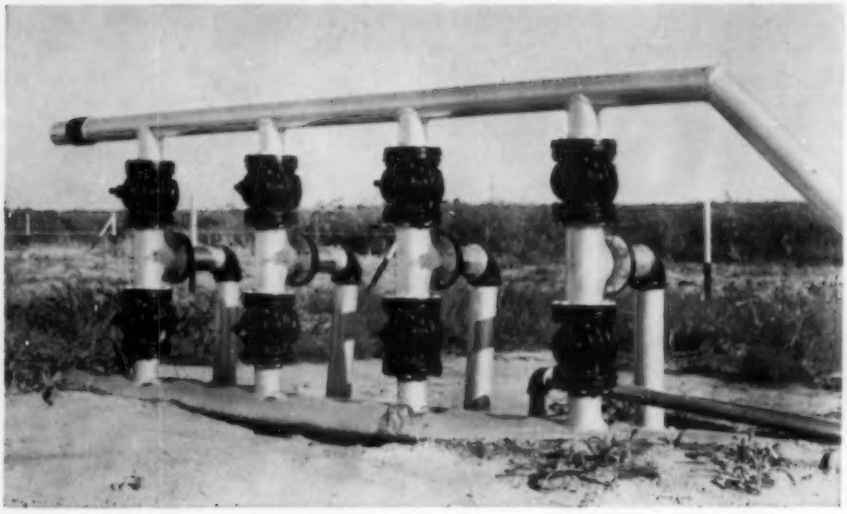
Sales offices: *Dallas, Houston, Corpus Christi and Midland, Texas; Tulsa, Oklahoma; Denver, Colorado; Los Angeles, California, and Cie. Ingersoll-Rand, Paris, France.*



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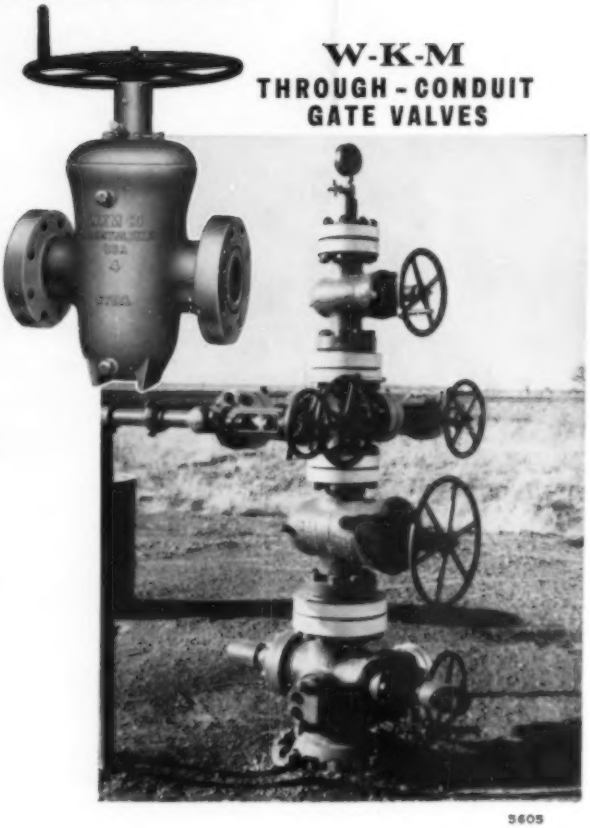

For your Christmas Trees, flow lines, and wherever else high pressures must be safely and positively controlled, there are the famous W-K-M- through-conduit gate valves, in working pressures from 1,000 to 15,000 pounds.

QCf lubricated plug valves, of steel, semi-steel, and special metals, with round or rectangular ports, in working pressures from 200 to 500 pounds—are the perfect companion valves for gathering lines, manifolds, headers, and similar low pressure installations.

Because you need the finest in service wherever valves are required, you will be way ahead when you specify W-K-M or QCf valves for their respective applications.

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The National Iranian Oil Company has vacancy for one experienced Petroleum Engineer to advise management on drilling, production and reservoir engineering problems. Salary commensurate with background and experience. Three years contract. Write giving full details such as age, marital status, education, details of previous experience, last salary, etc., to Embassy of Iran, 3005 Massachusetts Ave., Washington, D. C.

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PROCESS DESIGN ENGINEERS

Permanent responsible positions with opportunity for high calibre men in Engineering Department of large Gulf Coast chemical manufacturing plant. Applicants should have the following qualifications:

1. B.S. or advanced degree in chemical engineering.
2. Minimum of three years experience in process design calculations, pilot plant operations or production trouble shooting—preferably in organic plants.
3. Interest in detailed calculations and mechanical-chemical interpretation into practical designs
4. Interest in chemical engineering as a profession.
5. Ability to work with others in a team.

Positions are in Process Design Section for work on new plants and additions to existing plants. Work includes translation of pilot plant processes into full scale plant design, design calculations on distillation, heat transfer, mass transfer, fluid flow, and associated work necessary to prepare flow sheets (no drafting). Processes are both organic and inorganic. Some field date and production equipment performance evaluation involved. Small electronic computer to be available in this work. Assignments will allow for full recognition of individual's ability, with commensurate salary.

Replies held in strictest confidence; all will be answered. Please send complete resumé including education, experience, and salary expected, to **Mr. D. M. Duguid, Technical Employment Manager.**

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Favors Catastrophic Geology. Analyses past physical and chemical processes. *Order from author:* **D. J. Whitney,** Rt. 1, Box 355, Exeter, Calif. *Value received or money refunded.*

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The Dresser *Plus* ✦ is more than a catch phrase. It's the personification of the basic business operating philosophy of independently-managed Dresser companies. The Dresser *Plus* ✦ is another way of saying "teamwork." It's your assurance of a reputable world-wide source of equipment and technical services for the oil, gas, chemical and electronic industries.

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PERSONALS

Douglas C. Alexander, former treasurer of Reserve Oil & Gas Company, has been elected a vice president. Other new officers of the company are **Henry T. Fair, Jr.,** treasurer and assistant secretary, and **Robert E. Aberley,** assistant treasurer.

I. H. Hughes was named a vice president of Sunray Mid-Continent Oil Company. He will serve as assistant to President W. C. Whaley and continue as secretary to the company's salary policy committee. He has been with Sunray since 1954 as assistant to the vice president of production.

I. G. Davis, a veteran of 21 years of service with Gulf and vice president of Mene Grande Oil Company since 1951, has been elected to succeed **Hoyt Sherman** as Mene Grande president. Sherman resigned for health reasons.

Elected president in 1949, Sherman had been with Mene Grande since its formation, and in the oil industry since 1919.

L. A. Woodward has been elected administrative vice president of Kerr-McGee Oil Industries, Inc. He was formerly president of Mid-West Refineries, Inc.

A THOMPSON Pays Off and makes Drilling Rigs more Efficient...

Mud can become an expensive headache on drilling jobs. But smart operators and drillers everywhere are eliminating unnecessary loss of time, needless drilling expense. costly wear and tear on drilling equipment by using the Improved THOMPSON Rotating Shale Separator... equipped with the Sample Machine to provide specimens of formation cuttings.

A THOMPSON Separator effectively removes shale and abrasives from mud. Clean mud is fed back into the well. You're ahead... 'way ahead with a THOMPSON!

Manufacturers also of the famous THOMPSON Vibrating Shale Separator and Sample Machine.

THOMPSON TOOL CO.

IOWA PARK, TEXAS

SOLD THROUGH SUPPLY STORES EVERYWHERE

Cecil Cammack, senior attorney in Cities Service Oil Company's Texas legal division, has been transferred to the company headquarters as staff attorney. He joined Cities Service's legal staff in 1943 after serving almost five years as assistant attorney general for the State of Texas.

W. H. Paulson has been appointed regional manager of operations for Standard Oil Company of California, succeeding **C. C. Ward,** who has retired after 36 years of service with the company.

Cleve B. Bonner was elected treasurer of the Richfield Oil Corporation and **Norman F. Simmonds** secretary. Bonner, company secretary since 1937 and a director since 1941, succeeds **H. S. Nye,** resigned. Simmonds, who replaces Bonner as secretary, joined the company in 1928 and has been assistant to the president since 1940.

C. E. Peavy has resigned as district superintendent for Phillips Petroleum Company, Rocky Mountain district, to become vice president and manager of Britalta Petroleum Company in Calgary, Alberta, Canada.

P. H. Bohart, Gulf vice president of production at Tulsa, Oklahoma, will be transferred to Pittsburgh, Pennsylvania, as vice president, planning and economics. With Gulf since 1919, he also will be chairman of the economics review council.

S. G. Sanderson, manager of production for the Tulsa division since 1952, has been appointed division manager of the Tulsa production division, succeeding Bohart. Sanderson joined Gulf in 1913.

C. Haines Finnell has been appointed director of public relations and advertising for Union Oil Company of California.

T. Rieber has been elected to the newly-created office of chairman of the board of Barber Oil Corporation while Vice President **James H. Durbin** was named to succeed Rieber as president.

Rieber continues as chief executive officer, Durbin to direct and coordinate operations and administration. Previously Durbin was with American Republics Corporation and vice president of Barber Oil.

John H. Nason has joined Colorado Oil and Gas Corporation as vice president of its subsidiary, COG Minerals Corporation. He has been general manager of Olin Mathieson Chemical Corporation since 1954, and assistant to the executive vice president there from 1949.

Dr. Robert L. Slobod, formerly of the research and development division, Atlantic Refining Company, has been named head of the petroleum and natural gas department. He succeeds Dr. John C. Calhoun, who resigned to become dean of engineering at Texas A & M College.

W. B. Strobel, director of projects development in Continental Oil Company's petrochemical department, was selected to receive a 1956-57 Sloan Fellowship at the Massachusetts Institute of Technology. The fifth Conoco man to receive the Sloan Fellowship, he has been with the company since 1938.

▸ **W. W. Keeler** was elected executive vice president of Phillips Petroleum Company. With Phillips since 1929, he was elected vice president, executive department, in 1951, and a director of the company. Three years later he was elected a member of the executive committee. Since 1954 he has been chairman of the Military Petroleum Advisory Board.

K. E. Beall, vice president, economics department of Phillips, was advanced to the newly created position of vice president and petroleum consultant. **C. E. Turner** was promoted to manager of the economics department. Beall joined Phillips in 1920, transferred to the economics department in 1925, became its manager in 1946, and has been vice president in charge of the department since 1948. Turner, formerly manager of the economics department's reservoir division, started with the company in 1933 and in 1938 transferred to the economics department as manager.

M. D. Voss, with Phillips since 1941, has been promoted to manager of the reservoir division in the economics department, succeeding Turner, who was promoted to manager of the department.

▸ **D. L. Campbell, R. E. Kepke, J. L. Lenker** and **H. T. O'Neill** have been elected directors of the British American Oil Company Ltd. Campbell is vice president of manufacturing after serving as manager of that department for several years.

Kepke is executive vice president and an associate of the company since 1942. Lenker was appointed vice president of marketing earlier this year, and O'Neill is vice president and treasurer.

▸ Seven oilmen received awards for outstanding service to the industry at the American Petroleum Institute Division of Production April meeting in Columbus, Ohio.

Citations and Meritorious Service Awards went to:

E. H. Tollefson, Hope Natural Gas; **R. L. Bird Jr.,** Columbian Carbon; **W. H. Young Jr.,** Bradley Producing Company; **M. G. Gulley,** Gulf Oil; **L. N. Winkler,** Bethlehem Steel; **J. P. Bassett,** special assistant to division manager, Sun Oil; and **O. L. Martin,** production manager of the Turner Petroleum Company, and Michigan Oil Company.

▸ **Dr. Robert E. Wilson,** chairman of Standard Indiana, was named as 1956 winner of engineering's great honor, the Washington Award, sponsored by five leading engineering societies. As the 33rd recipient of the award he was cited for "unusual dedication of leadership, through science and engineering, to the advancement of research, industry, education and public affairs."

▸ **Nicholas J. Campbell Jr.** was elected a director of the Creole Petroleum Corporation. He began his service with Creole in 1947 as an attorney, becoming manager of the law department of the Caracas office in 1953.

Campbell succeeds **Lloyd G. Smith,** who retired after 43 years service. He began his career with the Standard Oil Company (Indiana) in 1913, and rose to his present position in 1947.

DEATHS

▸ **G. F. Gephart,** 57, comptroller of the Standard Oil Company of California, died in San Francisco, Tuesday, April 24, after undergoing major surgery. He joined Pacific Gasoline Company in 1922, which became a part of Standard of California in 1926.

▸ **John F. "Pat" Patterson,** 45, of Calgary, Alberta, Canada, manager of production for Husky Oil & Refining Ltd., died April 9 at a Salt Lake City hospital after a lengthy illness. He had been in the petroleum industry in the United States, Venezuela, and Canada for 22 years, and with Husky since 1947.

▸ **Ernest James Nicklos,** 75, pioneer oilman and chairman of the board of Nicklos Drilling Company and Nicklos Oil & Gas Company, died April 7. He entered the oil business at 16, and at one time was production vice president for Continental Oil Company.

▸ **William Wallace Rew,** 87, who retired in 1934 after 51 years in the oil industry, died April 15 in a Dallas hospital. He began his career in 1883, and through the years advanced from office boy, with Pierce Company to his last position as district manager of Magnolia Petroleum Company.

▸ **Morris Miller Slotnick,** 54, White Plains, New York, and a geophysical consultant with Standard-Vacuum Oil Company, died May 7 in Dallas, Texas, while on a business trip. Widely known in the petroleum industry as a research mathematician and geophysical interpreter, he originated and developed many of the basic and advanced methods of geophysical interpretation. One is known as the Slotnick Method of computing refraction data.

The One Pipe Wrench that
Out-performs
and Out-lasts
all others...

Genuine Heavy-Duty
RIDGID

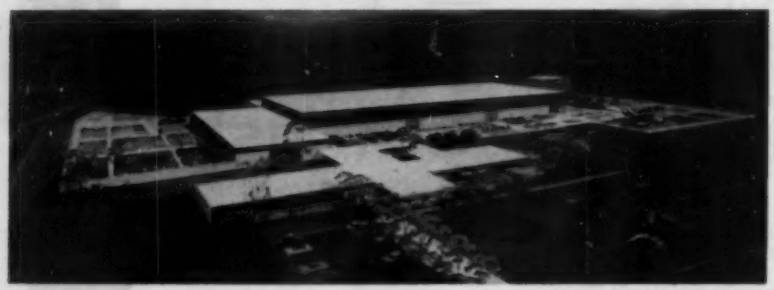
This pipe wrench does its job so well that millions of users swear by it.
It's extra strong and safe—sure jaw action aided by new patented hookjaw suspension.

Grips pipe or conduit instantly, no slip, no lock. Rugged comfort-grip I-beam handle ...handy pipe scale and easy-spin adjusting nut. Every wrench factory-tested, 6" to 60" ...to assure you *most* for your money. Buy RIDGIDs at your Supply House!

RIDGID
Work-Saver Pipe Tools

The Ridge Tool Company, Elyria, Ohio, U.S.A.

OIL and GAS TRADE NEWS



Multi-million dollar plant of the Insley Manufacturing Corporation and its subsidiary, The Maxi Corporation, is now under construction on a 35-acre site at Puente, California. Plans call for 150,000 sq ft of crane-covered production area plus air-conditioned offices for engineering, sales, and administrative personnel. Employees' facilities will include landscaped recreation terraces. George Vernon Russell and Associates are architects and engineers.

Production Increase Planned

Commercial Solvents Corporation will spend $10,000,000 during the coming year to expand production of methanol and petrochemical derivatives.

New construction will expand the Sterlington, Louisiana, methanol plant, and will also provide additional facilities at the Terre Haute, Indiana, plant.

Fourth Sulfuric Acid Plant

Stauffer Chemical Company has announced plans to build a new sulfuric acid plant, to cost approximately $2,000,000 at Dominquez, California.

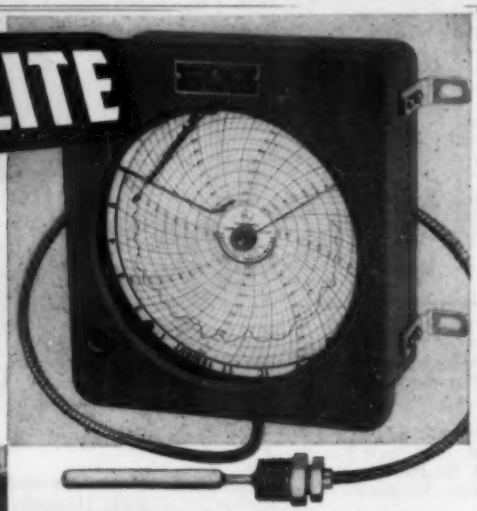
Construction has already begun with full scale production scheduled early in 1957.

Stauffer Chemical already has three sulfuric plants in California.

AUTO-LITE

...for TEMPERATURE RECORDING...

One of the many uses for Auto-Lite Recorders is the application shown below . . . a natural gas field meter run.



Auto-Lite Model "1000" Temperature Recorder has 6" chart. Various standard ranges from minus 40° F to plus 550° F. Available for wall mounting, portable or portable self contained use. Electric or mechanical chart drive. Choice of 24-hr. or 7-day cycle. Capillary tubing permits remote reading. Priced as low as $49.50. Manufactured to customers' specifications. Send for latest Catalog describing many types of Auto-Lite Recorders and Indicators.

THE ELECTRIC AUTO-LITE COMPANY
INSTRUMENT AND GAUGE DIVISION
TOLEDO 1, OHIO
NEW YORK • CHICAGO • SARNIA, ONTARIO

TEMPERATURE RECORDERS & INDICATORS

A-1 Bit & Tool Acquired

U. S. Industries, Inc., has acquired the assets of A-1 Bit & Tool Company of Houston, Texas, for 34,770 shares of USI's common stock.

A-1 Bit & Tool Company, which manufactures a line of special tools and valves used in the drilling and testing of oil wells, will retain its original name but will be operated as a branch of Garrett Oil Tools, Inc., division of U. S. Industries, Inc. Its annual sales have been running at the rate of about $2,000,000.

Hyster to Add to Peoria Plant

Hyster Company will erect a $150,000 factory addition in Peoria, Illinois, for expansion of facilities there.

The new addition will add approximately 25,000 sq ft to present plant facilities. Construction will start in June and completion is scheduled for November of this year. Permit for the building has been issued to O. Frank Heinz, general contractor.

Dresser Opens Washington Office

Opening of a Washington, D. C., office, establishment of a new governmental department, and the appointment of Urban Niblo, brigadier general, U. S. A. (retired) as director of government operations there have been announced by Dresser Industries, Inc.

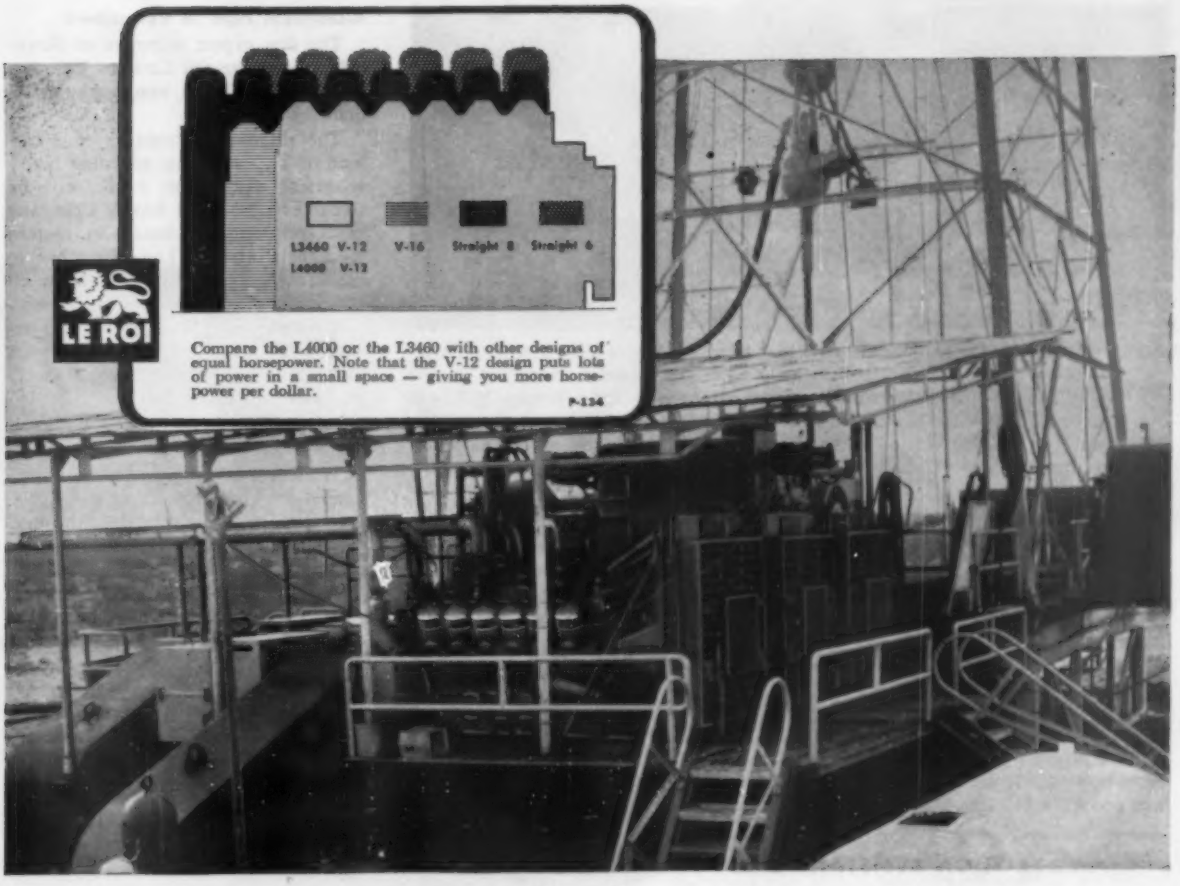
In his new position with Dresser, General Niblo will also have the responsibility of direction of industrial defense mobilization for Dresser as well as another important but subordinate function as Dresser's director of Civil Defense activities.

Security Expanding Sales Set-Up

Major expansion in the sales department of Security Engineering Division, one of the Dresser Industries, is continuing, necessitated by a threefold enlargement of the firm's Dallas, Texas, rock bit manufacturing plant.

E. L. McElwain, Casper, Wyoming, has been named assistant division sales manager for the Rocky Mountain division. Kenneth Ray Grumbles, Downey, California, has been promoted from sales engineer to district sales manager for the California district.

A new branch office for the Mississippi River area has been opened in Venice, Louisiana, Dan Molloy named as branch manager. Appointment of two additional field representatives in the Texas Gulf Coast area has been announced. L. A. "Pat" Simpson will headquarter at Liberty, Texas, and J. W. "Jake" Duran in Corpus Christi.


L3460 V-12
L4000 V-12
V-16
Straight 8
Straight 6
LE ROI
Compare the L4000 or the L3460 with other designs of equal horsepower. Note that the V-12 design puts lots of power in a small space — giving you more horsepower per dollar.
P-124

An engine doesn't have to be BIG to be POWERFUL!

The compact, V-12 design of Le Roi's L4000 and L3460 proves it!

Le Roi's L4000 and L3460 engines represent the first truly new design concept in 15 years. They are compact high-output engines, designed with short stroke to give you greater horsepower and speed without compromising engine life.

In addition to the advantages of short-stroke design, these modern V-12's have lightweight pistons, short-radius rotating parts — hydraulic tappets — crankshaft vibration dampener — sensitive controls. That's why they give you hair-trigger response to load demands.

The fuel economy of these engines is good, too. Thanks to advanced-design manifolding, low friction bearings, and low power loss to accessories, they give you rock-bottom fuel consumption.

Yes, big surprises come in small packages. That's especially true of the L4000 and L3460. These engines are conservatively rated to give you plenty of power in reserve. The L4000, for example, provides 635 max. hp. and the L3460, 600 max hp. And they have a wide speed range, too, up to 1350 rpm. That's why these engines are ideally suited to a great many oilfield applications: drilling, pipeline station, generator, gas booster, etc.

Engines may come bigger than these Le Roi's, but they sure don't come better! See for yourself — ask your supply house or Le Roi distributor to show you an L4000 or L3460 at work. Call him soon. Bulletins are also available — just write for them.

LE ROI *Division of Westinghouse Air Brake Co.*

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Oilfield Headquarters: Tulsa, Oklahoma

PORTABLE AIR COMPRESSORS

TRACTAIR

STATIONARY AIR COMPRESSORS

AIR TOOLS

ENGINES

An Award of Merit has been voted the Schlumberger Well Surveying Corporation's new research headquarters building in Ridgefield, Connecticut, by the American Institute of Architects in its annual competition for outstanding American architecture. The steel, glass, and brick air-conditioned structure contains a glass-enclosed relaxing library and patio. Lighting is combined natural and skylighting. Architect was Philip C. Johnson of New York City.

Million-Dollar Polyken Plant

A new million-dollar plant for manufacturing its Polyken plastic film and plastic adhesive tape coatings for corrosion prevention on gas lines, metal pipe, conduit and cable will be erected by The Kendall Company on a 76-acre site in Franklin, Kentucky.

The initial unit will provide 35,000 sq ft of floor space, more than tripling present production capacity. This new plant will have air conditioning to control process work.

Atlas Powder Patents Department

Atlas Powder Company has established a new department to handle license, patent, and trademark matters for all divisions and departments of the company.

Kenneth E. Mulford has been named to direct the new department. Mulford will also continue to serve as assistant to the vice president in charge of Atlas' chemicals division. Roger R. Horton, of the Atlas legal staff, has been appointed assistant director.

• CORROSION RESISTANT LINE
• 20 Ounce BRASS PLUMB BOB
• 50% HEAVIER LINE
EASY TO READ MARKINGS THAT ARE DURABLE
LUFKIN
"ATLAS" CHROME CLAD
OIL GAGING TAPE
Atlas lines are 50% heavier than standard weight steel tapes. Full 20-ounce solid brass plumb bob penetrates heavy oils. Easy to read. Bold black markings contrast with exclusive "glare-free" Chrome Clad surface — oil level shows clearly. Multiple platings prevent rust and corrosion. Wipes clean. Lines are replaceable. Lengths from 18 to 100 feet.
BUY LUFKIN TAPES • RULES PRECISION TOOLS FROM YOUR SUPPLY HOUSE
THE LUFKIN RULE COMPANY
SAGINAW, MICH.
New York City
Barrie, Ontario
BETTER MEASURE WITH LUFKIN
389

Aluminum Pipe to Venezuela

The first export shipment of Reynolds Aluminum Oil Country Pipe has left Houston, Texas, bound for the oil fields of Venezuela.

The shipment, consisting of a carload of 2, 3 and 4-in. schedule No. 5 seamless aluminum pipe, will be stocked by National Supply Company in warehouses at Anaco in eastern Venezuela and at Las Morochas in western Venezuela, the two major oil producing areas of the country.

Schedule No. 5 aluminum pipe is said to be ideal for temporary lines carrying oil, gas, water, or air at working pressures up to 500 psi.

GE Modern Electric Motor Plant

What is believed to be the most modern electric motor plant in the world, featuring highly mechanized production lines, has been unveiled in Schenectady, New York, by the General Electric Company.

This is said to be the first time electric induction motors in the 7½ to 30-hp range are being produced on a mass production basis.

The new plant was designed to meet a rapidly expanding total motor market. It was built at a cost of about $7,000,000 and began limited operations early in 1955.

The new plant makes extensive use of push button controls to machine, assemble, and test G-E Tri-Clad "55" induction motors.

South American Subsidiary

Procon, Inc., has announced the formation of a new subsidiary, Procon International, S.A., to handle its expanding petroleum process construction activities outside the United States.

While its operations are expected to be centered in South America, the new corporation's first major assignment is to construct all facilities for a 20,000 bbl-per-day refinery in Cuba for The Texas Company. The firm will have headquarters in Chicago, Illinois, and a branch office at Santiago de Cuba.

C. B. Whyte, president of Procon, Inc., also heads the international subsidiary. J. C. Reed and A. G. Petkus are vice presidents, J. E. Quinn, secretary, and A. J. Rohrman, treasurer.

American Welding New Officers

John J. Chyle, director of welding research, A. O. Smith Corporation, has been elected president of the American Welding Society for the 1956-57 fiscal year beginning June 1.

Other new officers are: First vice president, Clarence P. Sander, general superintendent, Vernon plant, Consolidated Western Steel Division, United States Steel Company; Second vice president, Gustav O. Hoglund, head of welding section, Alcoa Process Development Laboratory, Aluminum Company of America.

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Makes your work easier!

EVERYONE who specifies, buys and uses welding fittings and flanges has a mighty good reason for insisting on TUBE-TURN* products. *They simplify his work!* Being the world's most complete line, they *simplify piping design.* All available from one nearby source, they *simplify purchasing.* Of unsurpassed uniformity, they *simplify installation.*

These cost-cutting advantages are yours at no extra cost when you specify TUBE-TURN Welding Fittings and Flanges and buy from your nearby Tube Turns' Distributor. You get *more for your dollar* with this leading brand!

The Leading Manufacturer of Welding Fittings and Flanges

TUBE TURNS LOUISVILLE 1 KENTUCKY

A DIVISION OF NATIONAL CYLINDER GAS COMPANY

DISTRICT OFFICES: New York • Philadelphia • Pittsburgh • Cleveland • Detroit • Chicago
Kansas City • Denver • Los Angeles • San Francisco • Seattle • Atlanta
Tulsa • Houston • Dallas • Midland, Texas

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How TUBE-TURN Welding Fittings and Flanges

SIMPLIFY YOUR WORK

ENGINEERING

You can specify TUBE-TURN Welding Fittings and Flanges and know that you'll get the exact answer to your problem. The line includes all types in all piping materials, schedules and sizes. Also, Tube Turns offers you engineering assistance and helpful design literature.

PURCHASING

Tube Turns offers you outstanding distributor service . . . local stocks, geared for fast service. You can depend on this source for *all* your needs in welding fittings and flanges. *One order . . . one source* saves purchasing time.

INSTALLATION

Welders are enthusiastic about TUBE-TURN products because they fit up true, and elbows can be cut to odd angles with perfect alignment. Rigid inspection and quality control by Tube Turns assures absolute dimensional accuracy and uniformity.

NEW BOOKLET—This new Tube Turns' booklet gives helpful information on Pipe, Fitting and Flange materials. Mail the coupon for your free copy.

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Please send free copy of Pipe, Fitting and Flange Materials.

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TUBE TURNS

LOUISVILLE 1, KENTUCKY

A DIVISION OF NATIONAL CYLINDER GAS COMPANY

TRADE PERSONALS

J. Ernest Miller has been named vice president-sales for Goodrich-Gulf Chemicals, Inc. Miller was formerly sales manager for Goodrich-Gulf.

J. E. Miller

H. N. Stevens

Harry N. Stevens has been named director-research operating for the B. F. Goodrich Company. Stevens, who had been research coordinator in the company's research center, Brecksville, Ohio, joined B. F. Goodrich as a chemist in its Akron, Ohio, works laboratories in 1935.

Gordon G. Wilbur has been promoted to vice president, Ideco, one of the Dresser Industries. Wilbur, who has held various key positions in Ideco sales and technical service departments during the past 16 years, will now be in charge of export sales and have general administrative responsibilities.

Prior to his promotion, he was assistant to the executive vice president.

Earl Fuller has been named sales representative for the countries of Pakistan, India, Burma, British Borneo and Indonesia for Web Wilson Oil Tools, Inc. For many years Fuller has lived in Bandung, Java, Indonesia, which will be his headquarters.

C. L. Kirkman has been named manager of domestic sales for Lane-Wells Company, one of the Dresser Industries. Kirkman has been division sales manager for Lane-Wells Mid-Continent Division, with headquarters in Oklahoma City, Oklahoma.

C. L. Kirkman

R. C. Allan

R. Carson Allan has been appointed manager for The National Supply Company in Venezuela. He succeeds **J. S. Blair Jr.,** who was recently named sales manager, drilling equipment. Since 1954, he has served as district manager in western Venezuela.

Horace B. Horton has been elected chairman of the board of Chicago Bridge & Iron Company. Horton joined the company in 1907 and has been president since 1945.

Ernest E. Michaels, formerly executive vice president, succeeds Horton as president. **Charles S. Pillsbury,** formerly vice president and treasurer, was elected vice president and secretary, and **Arthur B. Horton,** formerly assistant treasurer, was elected vice president and treasurer.

George E. Borst, district sales manager of the New York City sales office, was elected vice president.

Phil C. Bennett has been appointed vice president and secretary of Republic Supply Company. As secretary he will replace **W. J. McWilliams,** who will continue as vice president and assistant to the president.

P. C. Bennett

Dr. J. H. Weigand

Dr. James H. Wiegand has been appointed vice president and technical director of Jet Research Center, Inc., a newly formed research and manufacturing company. Dr. Wiegand has previously been chairman, department of chemistry and chemical engineering, Southwest Research Institute.

He will direct the research and development activities of the center at Arlington, Texas, on improved shaped charges for oil well perforation.

Edward J. Hart has been appointed manager, RCA microwave equipment sales, for Radio Corporation of America. Hart for the past year has been microwave field sales representative in the eastern region.

James R. Fraser has been appointed chief engineer of The H. K. Ferguson Company. Fraser has served for several years as district chief engineer in charge of design activities of the company's central district, with offices in Cleveland, Ohio.

John G. Thiel, veteran company employee and former head of structural design in the central district, will succeed Fraser.

L. Glenn Rader has been appointed as vice president and general manager of sales for the Maloney-Crawford Tank and Manufacturing Company. Rader, former division manager at Houston, Texas, will make his headquarters in Tulsa, Oklahoma.

C. B. "Clint" Warren has succeeded Rader at Houston.

T. L. (Doc) Fontaine has been appointed executive vice president of Hunt Tool Company and will be directly responsible for the company's new expansion program.

He is resigning as sales manager for oil tools of Alco Products, Inc.

E. E. Finklea

T. L. Fontaine

Ernest E. Finklea has joined Schlumberger Well Surveying Corporation as assistant to the Mid-Continent area manager with headquarters in Tulsa, Oklahoma.

Prior to joining Schlumberger, he was employed by Geophysical Research Corporation as research engineer and later by Amerada as Log Analysist.

Harley Erickson has been appointed production manager for Eutectic Welding Alloys Corporation. Erickson was formerly general foreman of production for the Lincoln Electric Company and Westinghouse Electric Corporation, with more than 23 years experience in every phase of welding alloy manufacture.

Ray Long has been promoted by The Vapor Recovery Systems Company from the sales department at the factory to district manager of the Gulf Coast states area, with headquarters in Houston, Texas. **George W. Noyes,** Houston, will assist Long in sales engineering and service.

Tom Moughon

M. D. Lackey

Tom Moughon has been promoted to assistant chief engineer of Unit Rig & Equipment Company, and **M. D. Lackey** has been appointed development engineer.

Dewey R. Holcombe has been appointed manager of the chemical equipment sales department of the Pfaudler Company. Holcombe had been manager of the Detroit, Michigan, sales office prior to his new appointment and has been with the company since 1946.

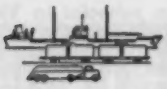
W. P. Maurath has been made branch manager at Cody, Wyoming, for McCullough Tool Company. Maurath has been a sales engineer in McCullough's Cody branch since 1954. He succeeds **William Newashe Jr.,** who has been transferred to Kimball, Nebraska, as branch manager.

How Standard invested its money last year to meet your growing oil needs

New Refinery Units to make higher octane gasoline took a big part of the $30 million we spent for plant improvement.

Petrochemicals for plastics and other new products; fertilizers and sprays for bigger crops, took a $20 million investment.

Research and technical services cost nearly $13 million. One result was a technique which promises to greatly increase yields from oil wells, helping conserve U.S. resources.



Transportation Facilities to bring our products from oil field to you were a $10 million item.

New and Modernized Service Stations from Alaska to Mexico cost $16 million, made Standard products more convenient for you.

Exploration for new oil sources cost $134 million. Standard Oil Company of California produced oil and gas from more than 8600 wells in the U.S., Canada and South America to supply your petroleum needs.

production-exploration *refineries* *asphalt refineries* *Standard marketing area*

STANDARD IMPROVED its ability to serve you last year by investing $347 million for new production and distribution facilities and exploration. The rest of our $1⅓ billion income was spent on such items as wages and benefits for our 36,369 employees, supplies from more than 10,000 U.S. firms and crude oil from independent producers. We paid a $107 million tax bill, and our 119,793 stockholders received 7¢ of each dollar we took in as a return on their investment in the Company.

If you wish a copy of our Annual Report for 1955, write to Standard Oil Company of California, Rm. 2153, 225 Bush St., San Francisco 20, Calif.

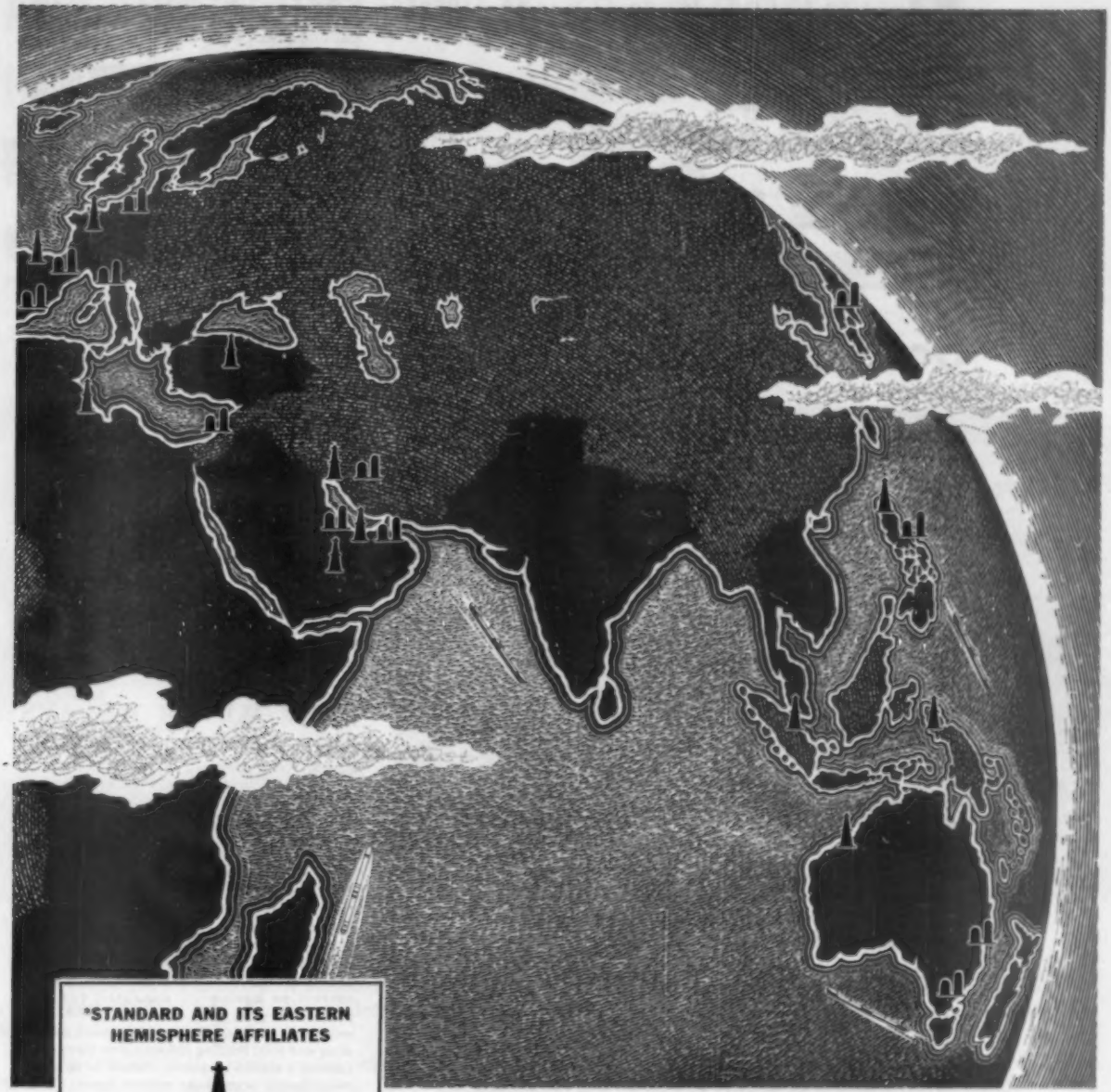
STANDARD OIL COMPANY OF CALIFORNIA

puts petroleum progress to work for you

Petroleum progress means...
to keep pace with your needs, oil companies must invest $74 billion in new U.S. facilities by 1965

Demand for petroleum products will increase about 50% over the next ten years

Part of Standard's earnings came from our work in supplying oil for other free nations



PARIS TAXIS, African river boats and Australian airliners run on gasoline produced by Standard's affiliates. Last year in addition to our Western operations, we* produced oil in 5 Eastern Hemisphere countries, processed it at 15 overseas refineries, supplied petroleum products to 67 countries outside the Iron Curtain. The result was a big boost for industry of Free World nations, conservation of U.S. oil reserves, and a higher standard of living for the peoples of many lands.

If you wish a copy of our Annual Report for 1955, write to Standard Oil Company of California, Rm. 2153, 225 Bush St., San Francisco 20, Calif.

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1956
PERMIAN BASIN
OIL SHOW

OCTOBER 18-21

Aerial view of show grounds showing completely enclosed exhibit buildings and a portion of the exhibit grounds. Note Boom Town Rig in foreground.

The 1956 show will again be presented at Fair Park, 42nd and Andrews Highway, Odessa, Texas. Exhibit buildings have improved. An additional 56,000 square feet of inside floor space has been added.

Contracts for exhibit space are now ready and reservations are being accepted. Contracts to previous exhibitors will be mailed this month.

This year's show will be the largest in history . . . the only really big show in the industry since 1954. Exhibits will feature latest developments in oil industry equipment and techniques.

If you are interested in exhibit space we urge you to write immediately for contracts and complete information. Address inquiries to:

Permian Basin OIL SHOW
219 W. Third · Odessa, Tex.

Plan now to SHOW and Go

. . . . . it's the Oil Field Worker's Show!

Trade Personals

▸ **Charles J. Vickers** has been named manager of technical sales-service of the Colfoam microballoon spheres department of Colton Chemical Company, a division of Air Reduction Company, Inc. Vickers was formerly associated with Allied Chemical and Dye Corporation.

C. J. Vickers

W. E. Scarborough

▸ **W. E. Scarborough** has been made assistant chief engineer for Security Engineering Division, one of the Dresser Industries. Scarborough will direct Security's field engineering services and will head engineering activities at the company's Whittier, California, plant.

▸ **Raymond G. Nordstrom** has been elected vice president and general manager of Reflectal Corporation, a subsidiary of Borg-Warner Corporation.

▸ **J. L. Mohun** has been appointed general sales manager, industrial insulation division of Baldwin-Hill Company. Mohun was previously general manager, Southwest division, with headquarters in Temple, Texas.

NEW METER-RELAYS
FROM 0-5 MICROAMPERES-UP

Ruggedized - Sealed, Black Bakelite or Clear Plastic Cases

D'Arsonval meters with locking contacts for sensitive and accurate control or alarm.

Model 461-C, 10-0-10 Ua DC **$83.25**

TRIP POINT ADJUSTABLE to any point of scale arc. Sensitive to changes as little as 1%. One contact on moving pointer. The other on adjustable pointer. When pointers meet, contacts close and lock. Holding coil wound on moving coil. Locking is electro-magnetic. Manual or automatic reset. Spring action kicks contacts apart.

Ranges: From 0-5 microamperes, 0-5 millivolts or 0-300°F up.

Standard Contact Rating 5 to 25 milliamperes DC. Can be up to 100 milliamperes DC.

Ruggedized-Sealed metal cases, 2½", 3½" or 4½" round, shock-mounted movement, gasket-sealed.

Black Bakelite case, 4½" rectangular.

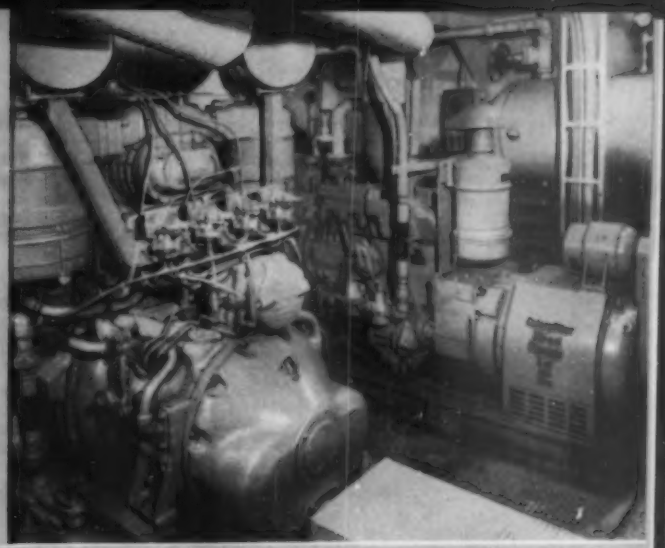
Clear Plastic cases, 2½", 3¾" or 4½" rectangular.

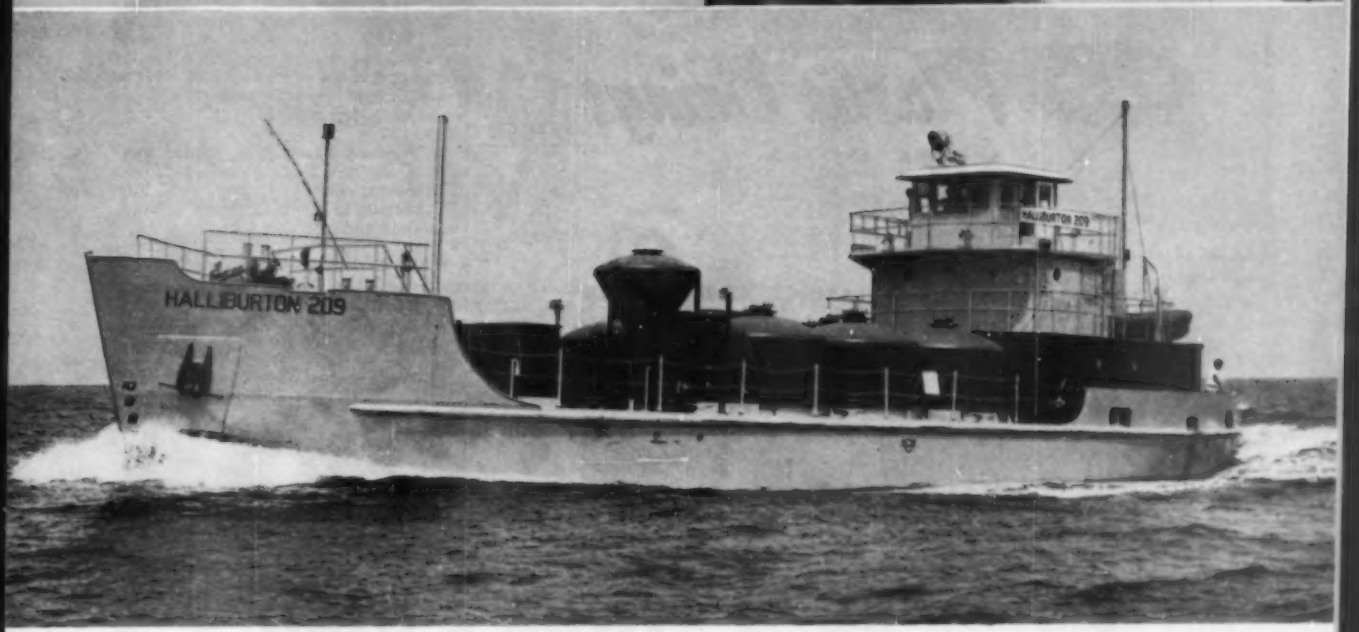
Model 255-C, 0-10 V DC **$42.50**

Panel meters and indicating pyrometers also in ruggedized-sealed, black bakelite or clear plastic cases. Write for new 40 page Catalog 4A on meter-relays, meters, pyrometers and automatic controls.

Assembly Products, Inc., Chesterland 48, Ohio. HAMilton 3-4436 (West Coast: Desert Hot Springs 48, Calif. Phone: 4-3133 and 4-2453).

FOR PROPULSION AND AUXILIARY POWER "HALLIBURTON 209" RELIES ON CAT* ENGINES





When the oil industry moved offshore, it turned to its dependable oilfield friends—modern heavy-duty Caterpillar Engines.

Halliburton Oil Well Cementing Co. selected two Cat D375 Marine Diesels for propulsion and two D318 Electric Sets for auxiliary power when it built its new twin-screw cementing ship, "Halliburton 209."

Powered by the D375s, the boat has a top speed of 10 knots. It is 124′ long, 31′ 6″ wide and draws 7′ 8″. It is capable of working far out in the Gulf or in marshy areas to provide cementing services wherever offshore drilling requires them. The "209" carries 5000 gallons of fuel, 10,000 gallons of fresh water, and 4500 sacks of bulk cement.

The D318 Electric Sets generate power to operate auxiliary pumps, air conditioning and radio facilities. Each also has a front power take off that drives an air compressor for the pneumatic conveying of cement.

For Halliburton, dependability is an absolute necessity. Costly offshore drilling operations cannot afford delays. Caterpillar Engines are designed for trouble-free, low-cost operation—they're always ready to go.

And now the Caterpillar line of Marine and Oilfield Engines is better than ever. New models have been added and existing engines have been improved to give you new highs in efficiency and economy at the same level of dependability. Whatever your power requirements, offshore or inland, there is a Cat unit built for the job.

Ask your Caterpillar Dealer to show you the complete line of engines up to 520 HP and 315 KW . . . and remember, he backs the superior quality of every Cat Engine with superior service and parts.

Caterpillar Tractor Co., Peoria, Illinois, U. S. A.

CATERPILLAR*

*Caterpillar and Cat are Registered Trademarks of Caterpillar Tractor Co.

MODERN HEAVY-DUTY DIESEL ENGINES

Trade Personals

Raymond L. Howerton has been promoted to assistant manager, sales promotion department of Hyster Company. Howerton has been manager of the sales training division of the sales promotion department.

Cummins Engine Company, Inc., has elected three new members to its board of directors, **H. E. Bollwinkel, C. R. Boll,** and **R. B. Stoner.**

Bollwinkel was also promoted from executive service manager to vice president - service. Boll is vice president - sales, while Stoner is vice president - personnel.

Morley Wilson is now vice president in charge of sales and service with Ace Mud Service, Ltd., of Estevan, Saskatchewan, Canada.

Maintenance Engineering Corporation of Houston, announces major promotions for the following: **Bert I. Thorngren** to vice president in charge of the chemical division; **Wilton H. Leverett,** vice president in charge of engineering, and **Edward B. Haldeman,** vice president in charge of sales.

Thomas J. Henry has been elected vice president in charge of sales of The Vortex Manufacturing Company. He was formerly national maintenance sales manager for The Glidden Company.

Glynn R. Kruger has been appointed chief process engineer of Procon, Inc. Kruger has been with Union Tank & Supply Company and Delta Engineering Corporation, both in Houston, Texas, in process engineering assignments.

Frank Williams has been named assistant sales manager of Waukesha Sales & Service, Inc. Williams joined Waukesha soon after World War II.

Frank Williams

E. L. Miller

Eugene L. Miller has been elected to the office of assistant general manager of The Cooper-Bessemer Corporation.

Miller's new capacity places him directly under the president and general manager, and with responsibility for the overall operations of the company. He had been assistant general manager of the engineering department.

Al W. Roth has been appointed manager of the new large propeller division of Aerovent Fan Company, Inc. Roth will continue to maintain offices at Tulsa, Oklahoma and at Piqua, Ohio.

Willis E. Jones was appointed to the position of sales manager of The Mercoid Corporations. **Paul J. Provost** has been named manager of the industrial controls division.

J. F. Weiffenbach

R. H. Morse III

Robert H. Morse III, formerly sales manager, has been elected vice president of sales for Fairbanks Morse & Company, while **J. F. Weiffenbach,** formerly chief product engineer, was elected director of engineering.

J. S. Peterson has been appointed manager of electronic sales, scale division.

L. A. Weom, who has for the past several years been manager of materials and schedules at the Beloit, Wisconsin, Works, has been appointed manager of the pump sales division with headquarters at Kansas City, Kansas. Weom succeeds the late Tom E. Woodruff. **J. R. Walsh** who has been manager of the company's Kansas City Pump Works since its opening several years ago, is succeeding Weom. **G. R. Anderson,** who has for many years been manager of the company's electrical works at Freeport, Illinois, succeeds Walsh.

A. H. Hoffman, who has for a number of years been manager of the company's Westco Pump Works in St. Louis, Missouri, has been appointed manager of the Freeport Works succeeding Anderson. **V. E. Johnson** has been transferred from the sales division to the manufacturing division, and has been appointed manager of the Westco Works in St. Louis succeeding Hoffman.

TK-2 Plastic Linings

APPLIED
BAKED
INSPECTED

under laboratory-strict conditions

Tube-Kote's exacting inspections, matching research laboratory standards, mark every processing phase of applying corrosion and paraffin resistant TK-2.

That is why more than 15 million feet of TK-2 plastic lined pipe is being used in major oil fields throughout the world—why more oil companies specify Tube-Kote TK-2 plastic lining for pipe protection than any other lining.

Learn the facts about TK-2, the plastic lining made best by 16 years of research, proved best by field use.
Write for 1956 TK-2 literature.

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TUBE-KOTE, INC.
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Houston 25, Texas

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MANUFACTURERS-EXTRUDERS OF PLASTIC PIPE FOR THE OIL INDUSTRY
Factory-trained field engineers available for consultation in all principal oil areas.

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OIL • GAS • WATER
PRODUCTS PIPELINES
PUMPING STATIONS

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18 TYPES OF PRODUCTS TO MEET YOUR SPECIFIC NEED

here's how!

to lick your
RING PROBLEMS!

Whether it's a packing or piston ring problem — FRANCE supplies not only the product *when you need it*, but the SPECIFIC Product to lick the problem.

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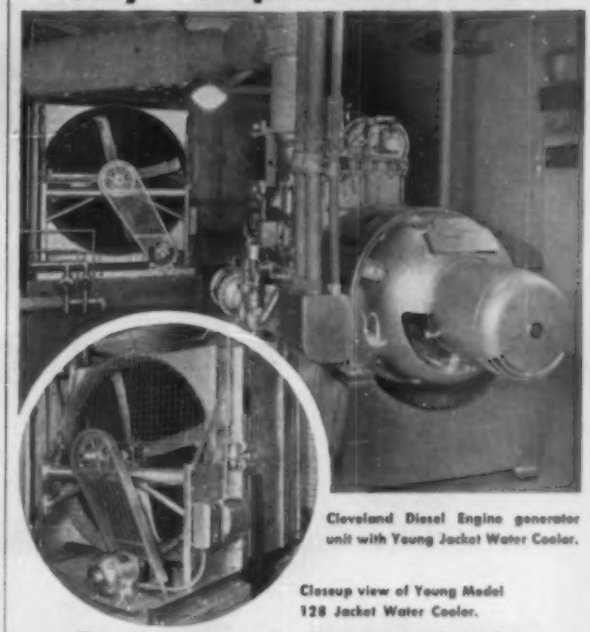


Cleveland Diesel Engine generator unit with Young Jacket Water Cooler.

Closeup view of Young Model 128 Jacket Water Cooler.

Emergency Power Unit
Cooled by Young Radiators

Take positive and dependable steps to prevent shutdown or impairment of telephone service when outside power sources are disabled or unavailable . . . this was the edict of the Wisconsin Bell Telephone Company. At Racine this challenge was met with the installation of an emergency power unit, a Cleveland Diesel Engine Division (General Motors Corporation) Model 4-268A engine. THIS ENGINE IS COOLED BY A YOUNG JACKET WATER COOLER. This radiator is used both to cool the engine jacket water and to provide suitably cooled water for use in the lube oil cooler of the engine. Another example of Young quality products entrusted with a job where absolute dependability is essential.

Get These Young Radiator Facts
Write Dept. 216-F for free catalog on Young radiators providing maximum cooling with minimum power consumption.

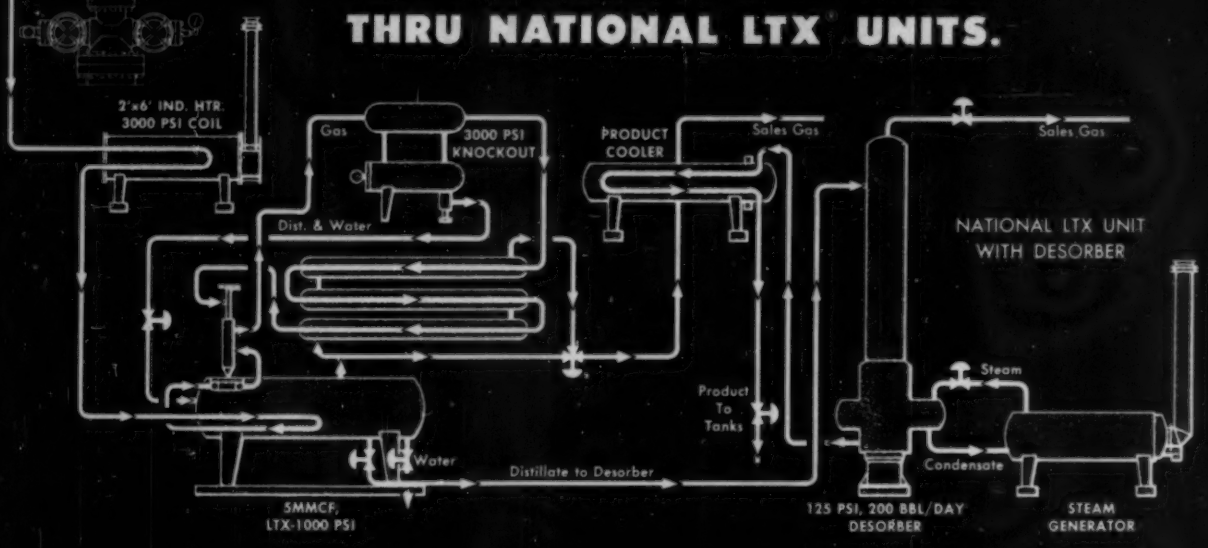
Put Young Talent
to work for you . . .

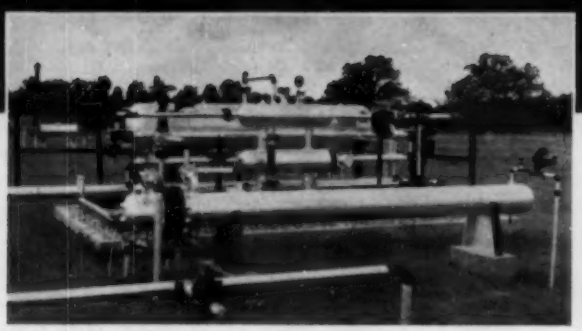
Solving heat transfer problems is what we do best because it is our very reason for being. You, too, can harness the power of Young engineering talent. Write, wire or call without obligation.

Young RADIATOR COMPANY
RACINE, WISCONSIN
Creative HEAT TRANSFER ENGINEERS FOR INDUSTRY
Heat Transfer Products for Automotive, Aviation and Industrial Applications. Heating, Cooling, Air Conditioning Products for Home and Industry.
Executive Office: Racine, Wisconsin. Plants at Racine, Wisconsin, Mattoon, Illinois

Increased Revenue!

THRU NATIONAL LTX UNITS.





Installation of a National LTX Unit with desorber on this gas distillate well near Shreveport, Louisiana, INCREASED the recovery 14 barrels of stock tank liquid per MMCF of sales gas produced.* The well originally tested 70 barrels per MMCF with conventional separation equipment and increased to 84 barrels per MMCF of sales gas produced after the installation of LTX equipment. The LTX unit operates at approximately 300 psi and 5°F. Flowing pressure is approximately 2500 psi.

To receive maximum recovery from your lease, contact a National Tank Company representative in your area. You will find him nearby with "know how" and production equipment ready to serve your producing needs.

**For a more finite economic evaluation, the differences in recovery should be based on the unit of well effluent. This is not data that can easily be observed in the field for it requires calculations based on the wellstream hydrocarbon composition. Such determinations are often valuable.*

It's a National®

NATIONAL TANK COMPANY

TULSA, OKLAHOMA

PACKAGED drilling

at lowest cost . . .

with FRANKS *Comet* Trailer-Rig

Lower initial cost drilling rig with lower daily operation cost and lower moving and rig-up, as well as smaller diameter hole, is required if maximum economics are to be effected.

Franks Comet trailer rig with packaged drawworks, derrick, engines, substructure, pipe rack (as shown above) on two trailers, has all the fundamentals required by the developers of small hole drilling. The Franks Comet needs only guying to rig front end. It moves strung up. Capacity 10,000 ft. slim hole and 6,000 ft. standard drilling.

Only Franks offers "on the spot" field service with stock of parts and factory-trained personnel available at Alice, Compton, Casper, Farmington, Great Bend, Houston, Kilgore, Odessa, Pampa, Seminole, Edmonton, and Tulsa.

Call a Franks representative to discuss how Franks trailer-mounted drilling rigs can make you money.

FRANKS
DIVISION CABOT SHOPS INC.
WELL SERVICING AND DRILLING UNITS
TULSA, OKLAHOMA

"ON THE SPOT" FIELD SERVICE

CABOT SHOPS INC.

LANE-WELLS SERVICE

VALVE SEAL
of special material operates even with junk on seat.

FULL-DIAMETER MANDREL
allows free passage of tools.

"FLOSEAL" PACKING RINGS
have controlled expansion, spring back to shape and don't "vulcanize" to casing.

"FREE-WHEELING"
slip rein ring allows cage to turn without wrenching slip reins.

LARGE BYPASS
means fast running in fluids.

"SLYDEZE" SLIPS
with permanently-lubricated backs, are dovetailed into cone—can't get out to hang up the packer. Cross-cut wickers hold fast on hardest casing, don't damage casing.

LIFTING LUGS
inside packer insure easy release of packing element.

these field-proved features show why operators are getting

POSITIVE SETTING
LEAK-PROOF PACKOFF
EASY PULLING
LONGER LIFE

with

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LOS ANGELES • HOUSTON • OKLAHOMA CITY • LANE-WELLS CANADIAN CO. IN CANADA • PETRO-TECH SERVICE CO. IN VENEZUELA

Of Things To Come . . . In Oil

ROCKY MOUNTAIN ACTIVITY ON INCREASE . . . nearly 25 per cent ahead of first four months in 1955. Northern New Mexico and western Nebraska increased over 100 per cent . . . wildcatting up 85 per cent. San Juan Basin activity will hit its stride this month. A slight decline was experienced in Wyoming, although exploration drilling is up 51 per cent over last year. Look for more drilling in North Dakota after a slow "warm-up" of activity which exceeded that of last spring by 30 per cent.

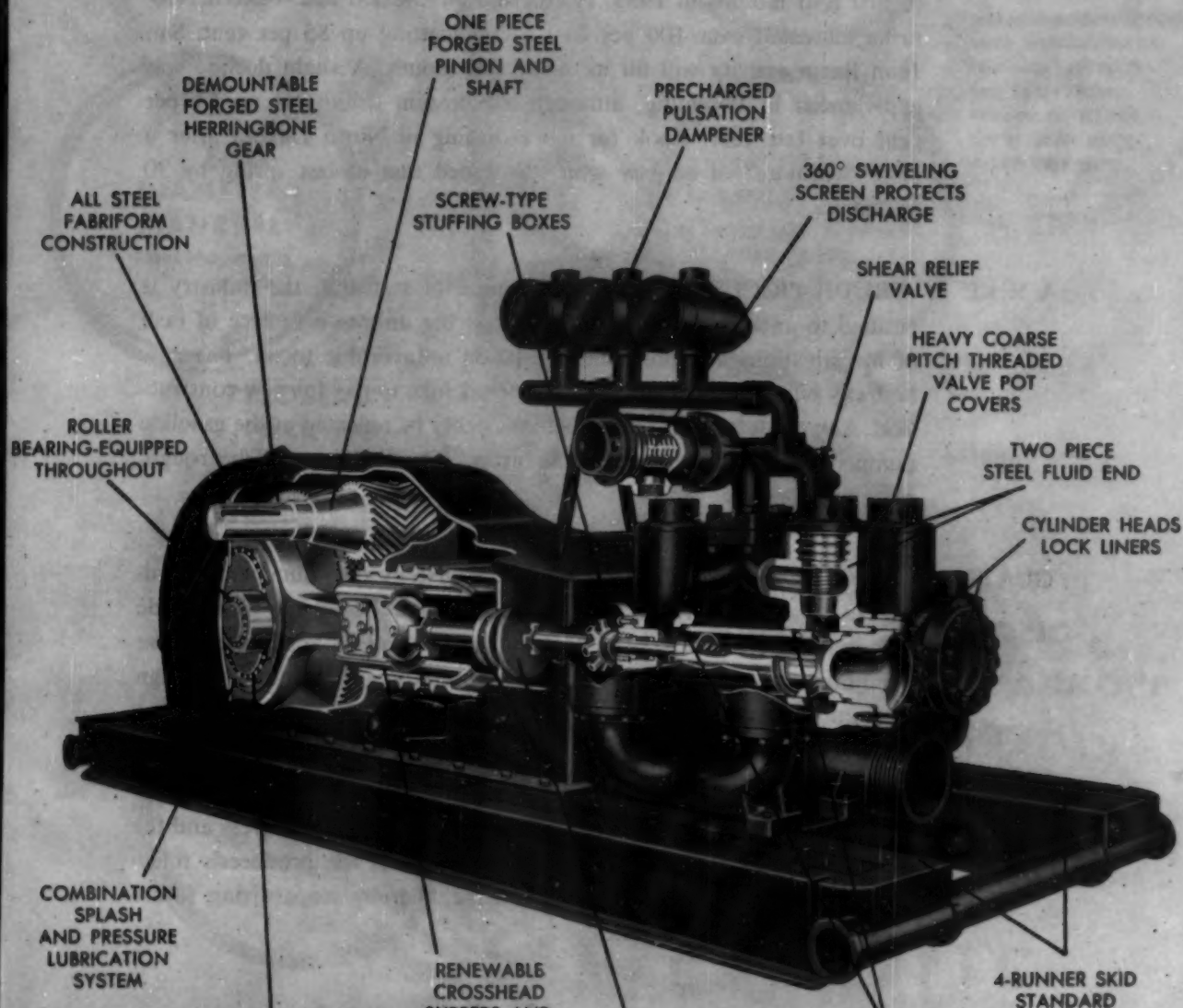
A HIKE IN CRUDE PRICES? Judging by the maze of statistics, the industry is entitled to an increase. Public reaction is big unknown in face of rash of investigations and proposed legislation unfavorable to oil. The new highway bill calls for a federal gasoline tax hike to pay for new construction. Any crude price increase will invariably be reflected at the gasoline pump. Will it help or hurt the industry? The sledding will be rough, price hike or not.

GUATEMALA TO GRANT FIRST OIL CONCESSIONS by early summer, according to Rodrigo Cordova Cerna, chief of the Direccion General de Mineria Hidrocarburos. May 25 was deadline and 29 applications have been made when this Latin American country opened it doors to foreign operators.

A SOFTER ATTITUDE by gas distributors toward producers is evidenced by the utility companies' concern over a gas bill acceptable to congress and the president. Reason behind their new approach is the producer's reluctance to sell gas to interstate commerce, thereby jeopardizing future supplies of gas to the utilities.

MOVE TO DIVORCE gas transmission companies from oil and gas exploration, development and production is under serious consideration by independents who feel that the transmission companies have certain economic protection under law not enjoyed by independent producers.

LET'S TAKE A LOOK AT THE INSIDES OF THE POWERFUL, PORTABLE, LIGHTWEIGHT....


ONE PIECE FORGED STEEL PINION AND SHAFT
DEMOUNTABLE FORGED STEEL HERRINGBONE GEAR
PRECHARGED PULSATION DAMPENER
360° SWIVELING SCREEN PROTECTS DISCHARGE
ALL STEEL FABRIFORM CONSTRUCTION
SCREW-TYPE STUFFING BOXES
SHEAR RELIEF VALVE
HEAVY COARSE PITCH THREADED VALVE POT COVERS
ROLLER BEARING-EQUIPPED THROUGHOUT
TWO PIECE STEEL FLUID END
CYLINDER HEADS LOCK LINERS
COMBINATION SPLASH AND PRESSURE LUBRICATION SYSTEM
RENEWABLE CROSSHEAD SLIPPERS AND FRAME GUIDES
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ONE-PIECE ECCENTRIC STRAPS EQUIPPED WITH LARGE DIAMETER, HIGH CAPACITY, RETAINED TYPE ROLLER BEARINGS
PACKING GLAND AND RUBBER BAFFLE PROTECT POWER END FROM MUD
LINERS PACKED AT BOTH ENDS AND EXPOSED TO VIEW

EMSCO SLUSH PUMPS

Learn how Sound Engineering and Advanced Techniques of Fabrication, Metallurgy and Precision Machining combine Powerful Performance with Lightweight Construction

See for yourself the many exclusive built-in features!

Note "Fabriform" construction of power end frame.

No matter what your mud circulating requirements are, you will find an EMSCO Slush Pump to meet your needs. There are six models, D-175, D-300, DA-500, D-700, D-850, and D-1000, for shallow, medium and deep drilling, for jet bit or big hole. Each model is a masterpiece of advanced design and skilled workmanship and is built for heavy duty performance under tough conditions, yet is lightweight and offers maximum portability.

Call your nearest EMSCO representative today and learn more about EMSCO Slush Pumps.

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Houston, Texas • LOS ANGELES, CALIF. • Garland, Texas

General Sales Offices: Dallas, Texas

Distributors: Bovaird Supply Company, Tulsa, Oklahoma
Mid-Continent Supply Company, Fort Worth, Texas
Export distributor: Mid-Continent Supply Company, Inc., 45 Rockefeller Plaza, New York 20, N.Y.

SP-601

because of this spring

Johnston is tops in testing

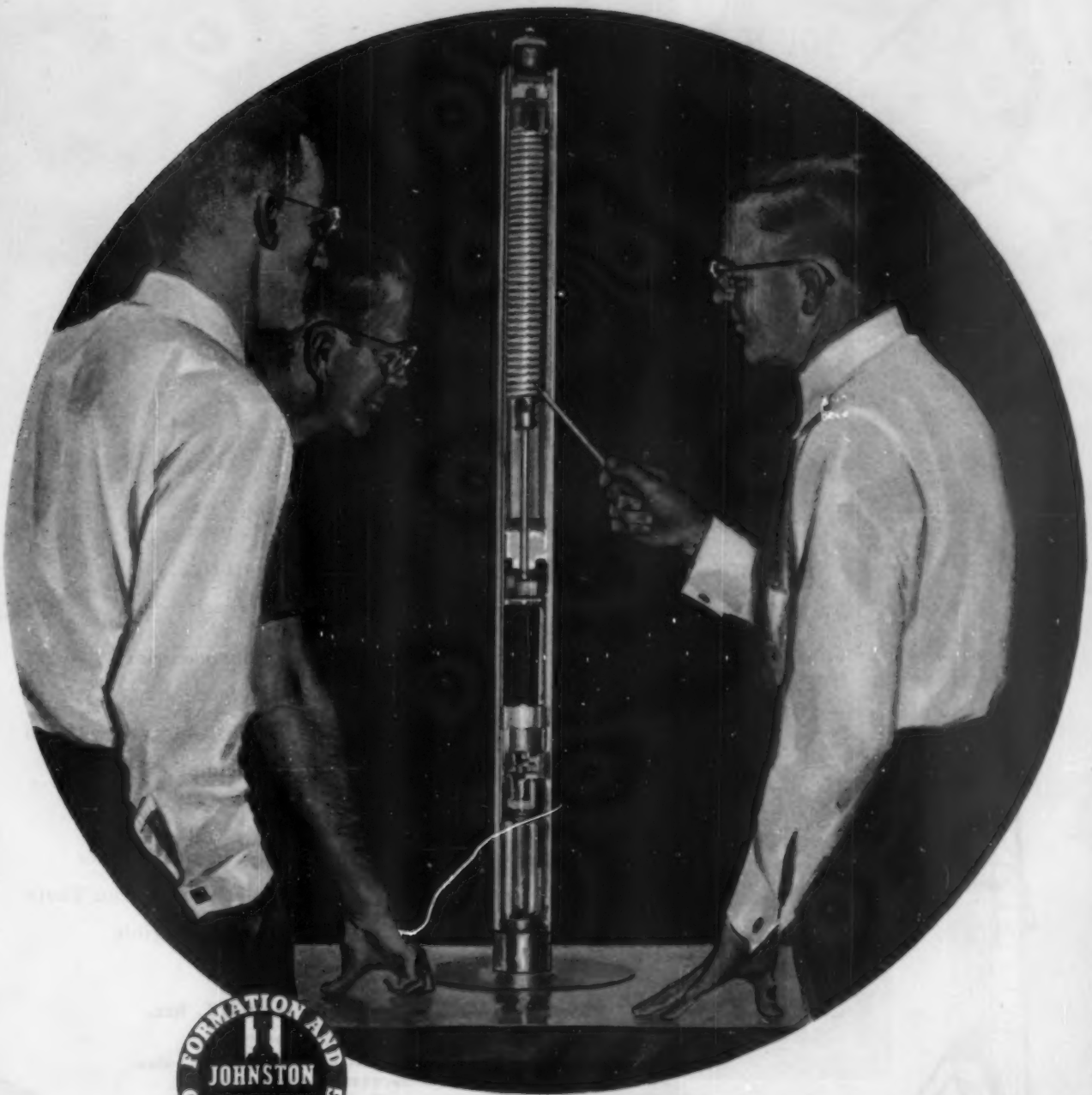
Actually, this chrome vanadium steel spring is only one of many reasons why Johnston Is Tops In Testing. A noteworthy achievement in metallurgy, its ultra low thermal coefficient and its ability to deflect up to five inches under pressure makes it the ideal tension member for pressure recording instruments. Thus, in sensitivity, accuracy, and behavior under high bottom hole temperatures, it is far superior to any other formation pressure measuring device. For example, on standard field 0-7000 psi range instruments, pressure changes of only 2½ pounds are observed continuously . . . a sensitivity of 5/100 of 1 per cent!

A rugged built-in thermometer and chronometer leave nothing for the imagination. Only a final completion can provide a more accurate productivity index.

So, why be satisfied with an approximate reservoir evaluation when Johnston Testers enable your engineers to see the true picture?

JOHNSTON

first in drill stem testing



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JOHNSTON

A Subsidiary of Schlumberger Well Surveying Corporation

TESTERS

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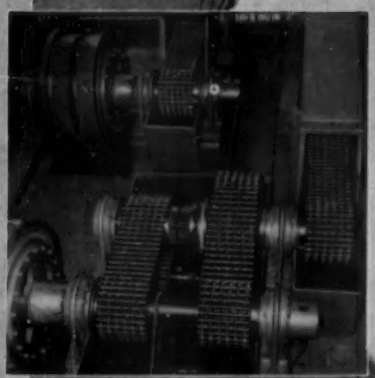
LOS ANGELES, CALIF. • CALGARY, CAN.

DOWN TO VENEZUELA GO DIAMOND ROLLER CHAIN DRIVES ON THE NEW TRAILER-MOUNTED UNIT RIG-15

VENEZUELA



Portability, quick rig-up and tear down and *dependability* are prime requisites of this new type export rig now being used in Eastern Venezuela.

In this rugged service, breakdowns are exceptionally costly and time consuming—there can be no substitute for *performance.* On this U-15 you will find Diamond Roller Chains compounding six hundred horsepower for the drawworks.

On leading rigs everywhere, Diamond Roller Chains are first choice as standard equipment. Their outstanding quality and long life is tangible proof of economy on the job.

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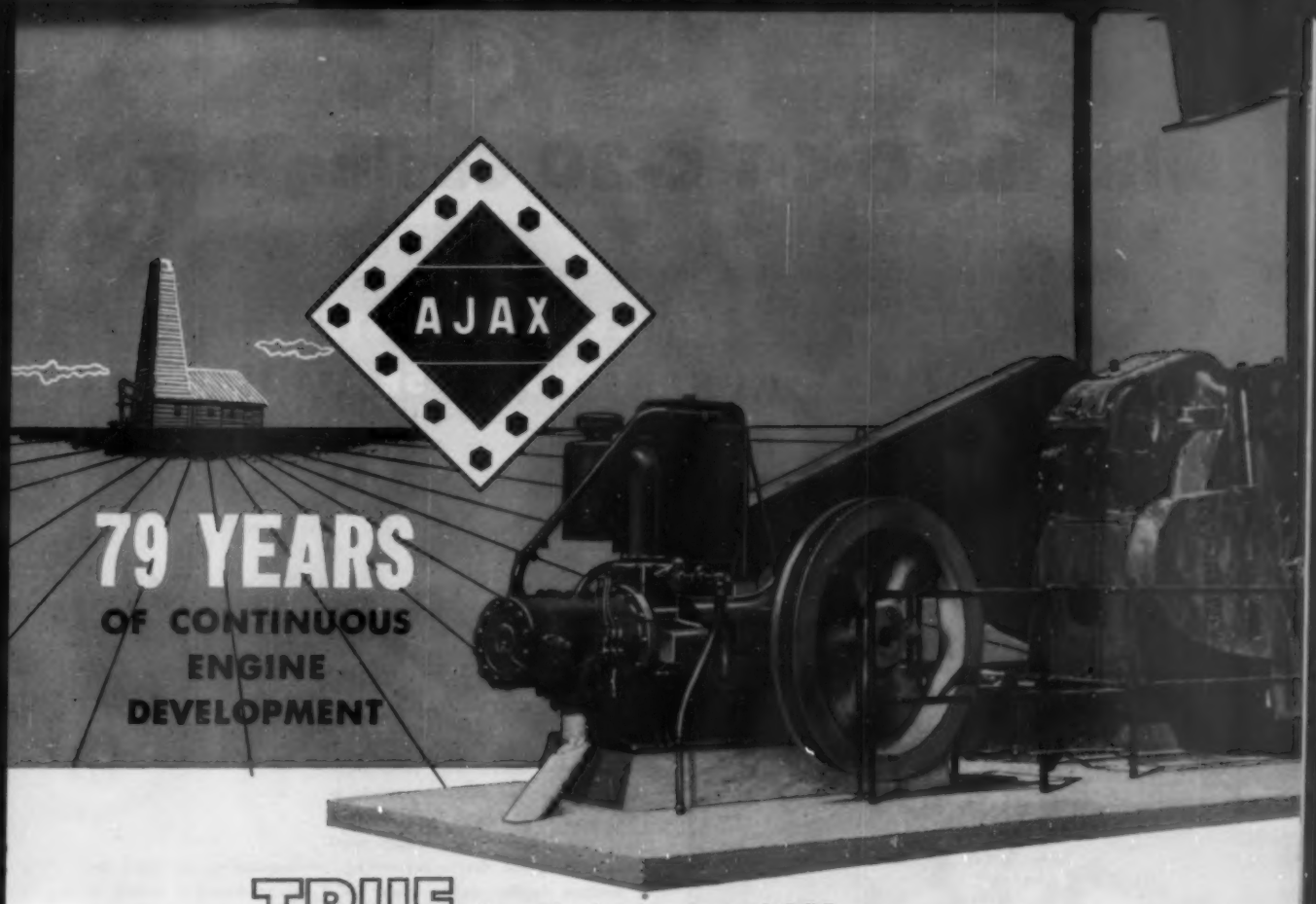
Please refer to the classified section of your local telephone directory under the heading CHAINS or CHAINS-ROLLER

DIAMOND ROLLER CHAINS



TRUE *since the beginning of OIL . . .*

A SINGLE CYLINDER DOES IT BEST

The cheapest and most dependable power in the oil producing business has always been provided by the horizontal, two cycle, crosshead type gas engine. This was true for the old-timers and it's true today. The only difference is in the engines!

Today's Ajax Gas Engine is a highly-engineered, precision product. Retaining all the essential simplicity of its great prototype, the Ajax you buy today is a product of the best design, the finest craftsmanship and the most suitable materials it is possible to obtain.

And Mr. Producer, if gas is obtainable, Ajax will deliver cheap power! *Ask your Supply Man for the particulars.*

Ajax MODERN GAS ENGINES

- SINGLE CYLINDER
- HORIZONTAL
- TWO CYCLE
- LOOP-SCAVENGED
- CROSSHEAD TYPE
- THERMO-SYPHON COOLING

for

ECONOMY
SIMPLICITY
LOW MAINTENANCE
CONTINUOUS DEPENDABILITY
LONG USEFUL LIFE

AJAX IRON WORKS

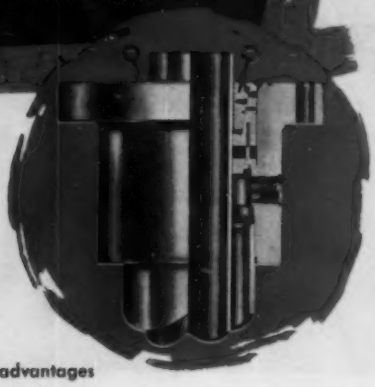
Builders of GAS AND OIL ENGINES, PRESSURE PUMPS, STEAM DRILLING ENGINES, INDUSTRIAL STEAM ENGINES

CORRY, PENNSYLVANIA

Oil Field Distributors: THE NATIONAL SUPPLY CO., PITTSBURGH, PA.
R. B. MOORE SUPPLY CO., BOLIVAR, N.Y. • BETHLEHEM SUPPLY CO., TULSA, OKLAHOMA

with the O·C·T C-20 Casing Head

YOU DON'T REMOVE PREVENTERS UNTIL CASING IS SET AND SEALED!



Combining field-proved advantages with new engineering advancements, the Oil Center Tool Company "C-20" Casing Head provides operators with the first quick-setting, positive-sealing wellhead for medium depths. This original O-C-T design means a saving of costly rig time with simplified installation and added safety in the completion operation before removing blowout preventers. The sealing element, slip bowl and slips are assembled as a single unit that may be wrapped quickly around the casing, latched and dropped into place — thus eliminating the possibility of individual parts being installed incorrectly. All work can be done on the derrick floor without entering the cellar to install slips and seal assembly. The resilient seal ring provides an effective seal for the life of the well in any climate. Available through more than 700 supply store locations.

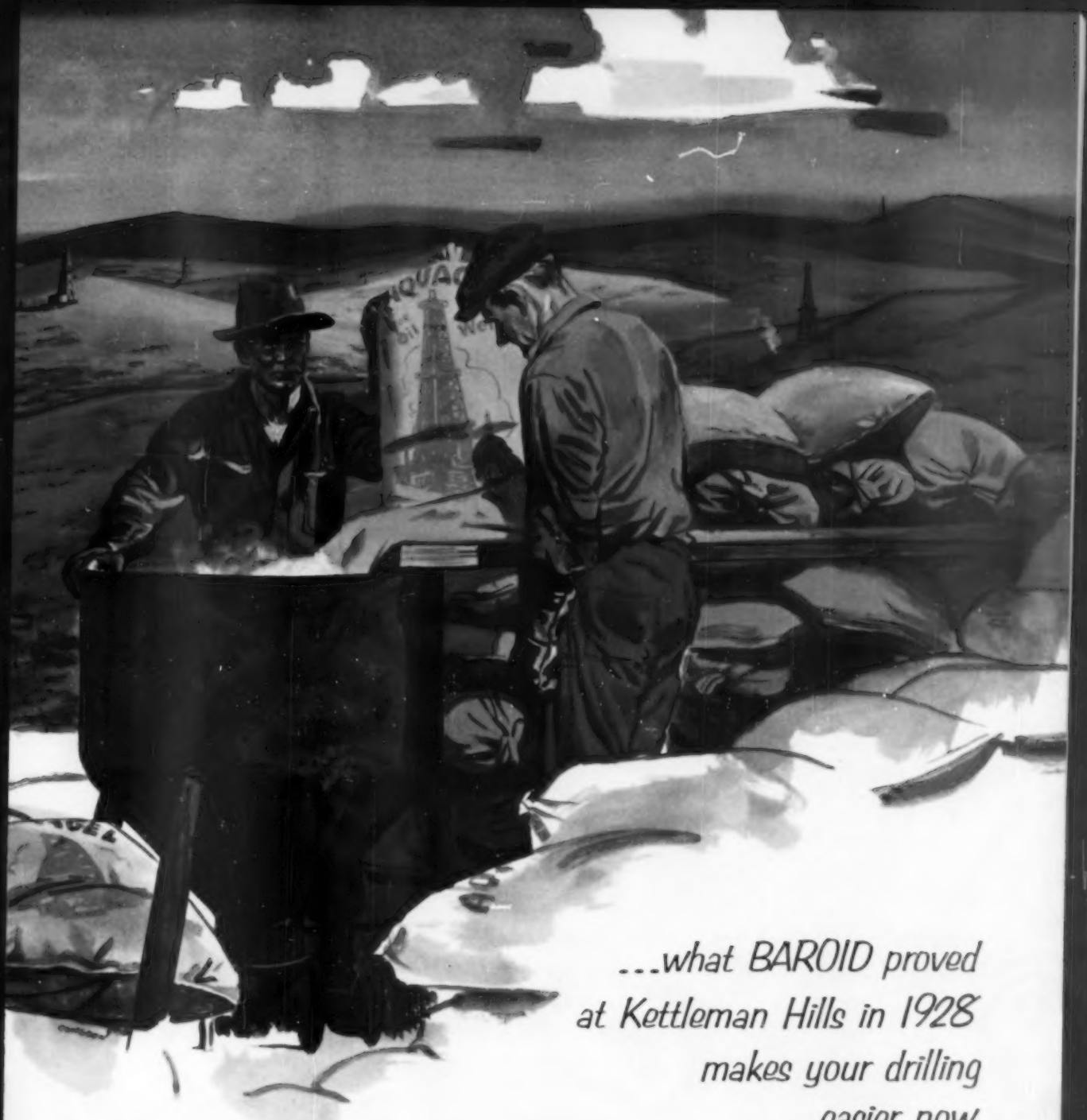
O·C·T

OIL CENTER TOOL CO.

P. O. Box 3091, Houston, Texas

THE O-C-T TYPE JCW PRODUCTION PACKER

Isn't it time you found out about this O-C-T Packer? It runs, sets and pulls without any difficulty. It's a competitively priced premium packer.



...what BAROID proved at Kettleman Hills in 1928 makes your drilling easier now

In 1928, Aquagel for drilling mud was first used on one of the initial producing wells in California's famed Kettleman Hills field. This was a last, but successful, attempt to save the hole from caving shales and complete the well. This corrective treatment for caving shale pointed the way to successful drilling of these formations everywhere. Then, as now, Baroid led in drilling mud products and development.

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IS PORTABLE
Example: improved pH meter, smallest size yet!

BAROID EQUIPMENT
IS ACCURATE
Example: new high-temperature filter press with back pressure receiver.

FOR ANY TEST of DRILLING MUD

in field or laboratory

BAROID EQUIPMENT
IS DURABLE
Example: kits in rugged stainless steel cases.

BAROID EQUIPMENT
IS COMPLETE
Example: filtrate analysis and pilot testing kit.

Baroid has the precise equipment for the job. Conforms to API recommendations. Write today for complete catalog.

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Please send me your complete Testing Equipment catalog.

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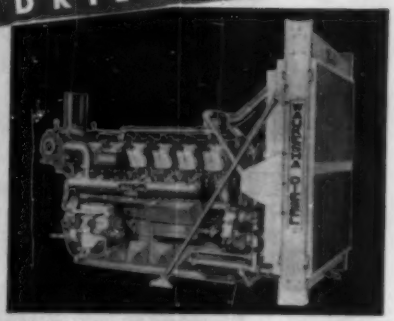
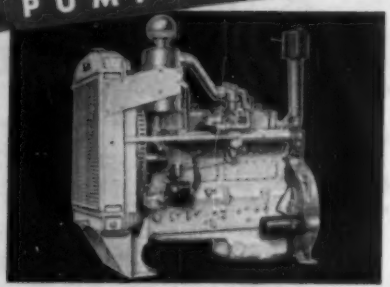


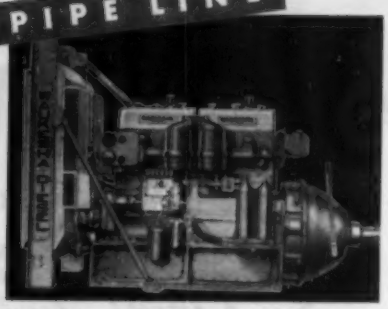
VLRDBSU Turbocharged Diesel Unit—twelve cyl., 8½-in. bore x 8½-in. stroke, 5788 cu. in. displacement, 1100 hp at 1200 rpm, maximum.

PUMPING



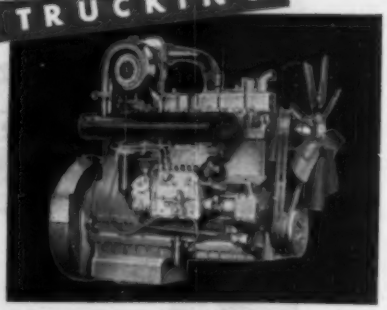
145-GZBU Gas Power Unit—six cylinders, 5⅜-in. bore x 6-in. stroke, 817 cu. in. displacement, 176 hp at 2000 rpm on natural gas.

PIPE LINE



NKDBU Normal Diesel Power Unit—six cylinders, 7-in. bore x 8¼-in. stroke, 1905 cu. in. displacement, 274 hp at 1200 rpm, maximum.

TRUCKING



148-DKBS Turbocharged Truck Diesel—six cylinders, 5¼-in. bore x 6-in. stroke, 779 cu. in. displacement, 280 hp at 2100 rpm.

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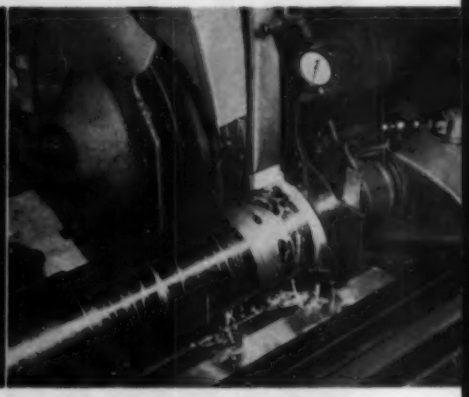

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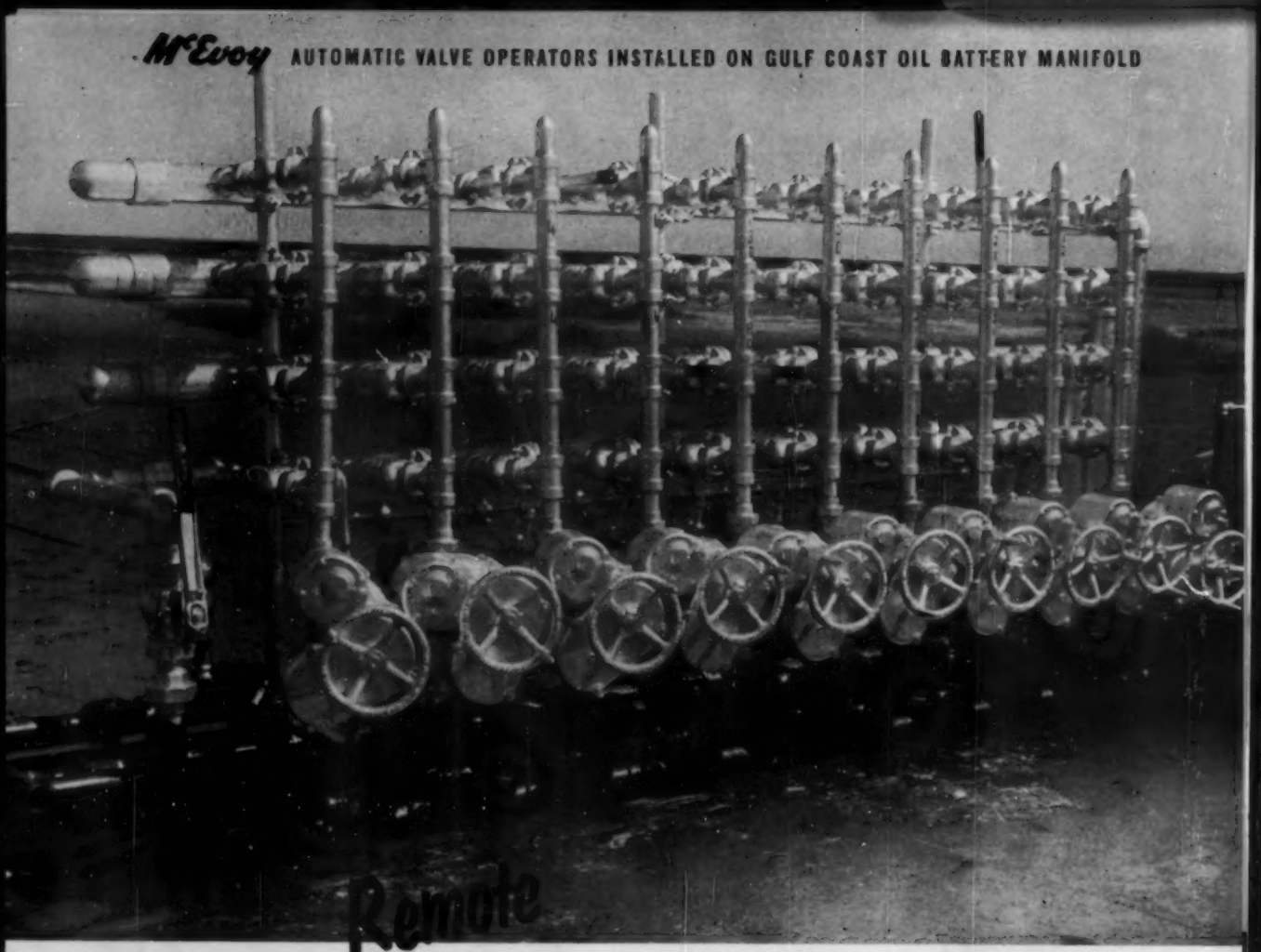

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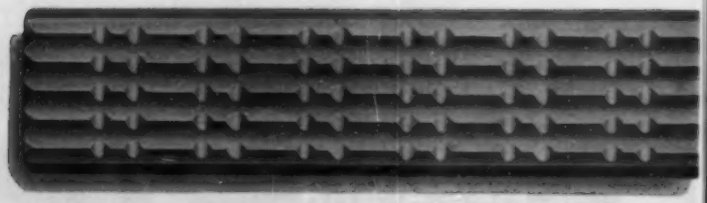

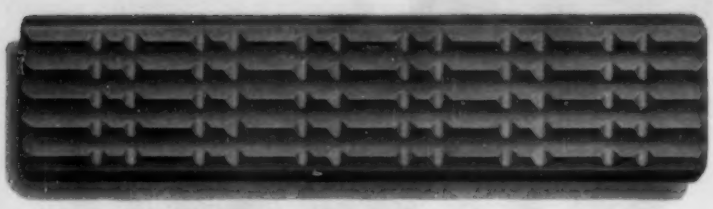

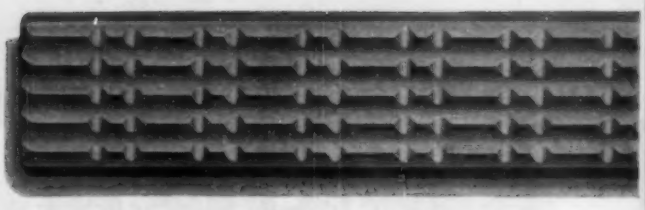

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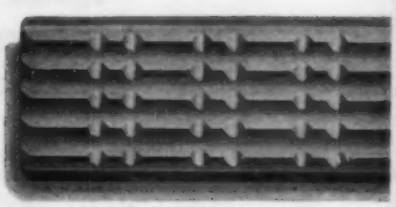

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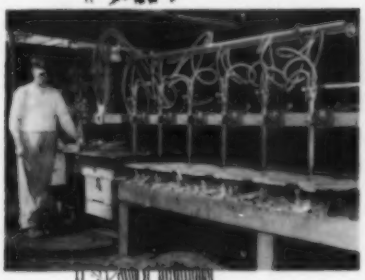

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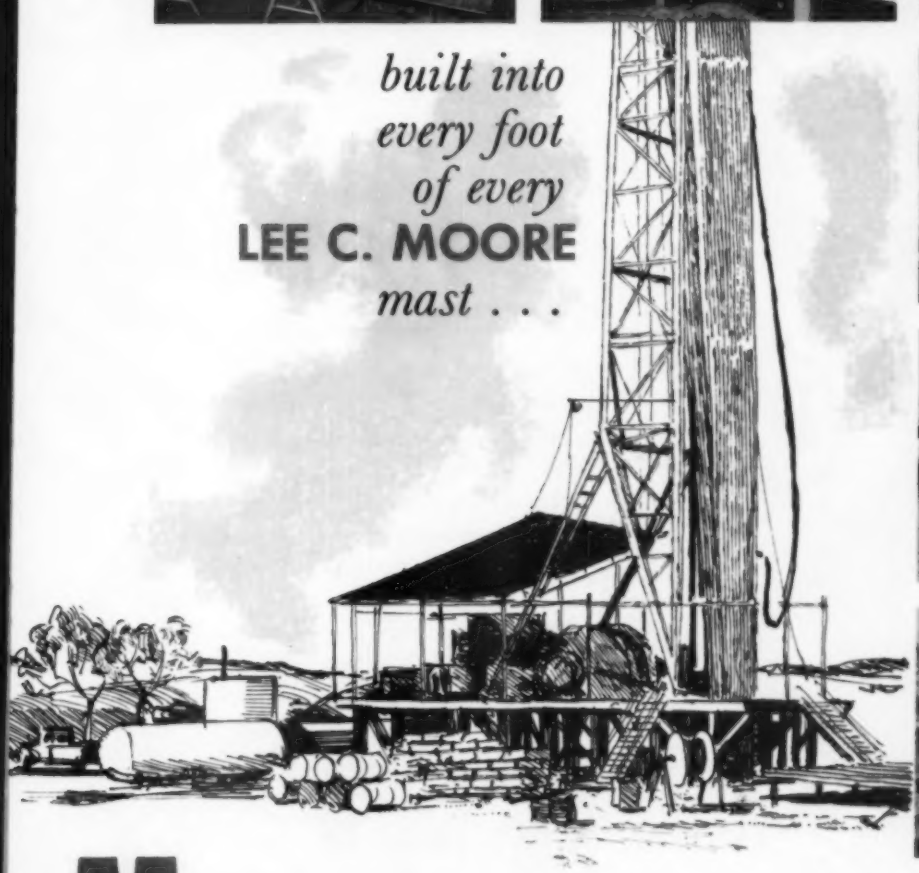

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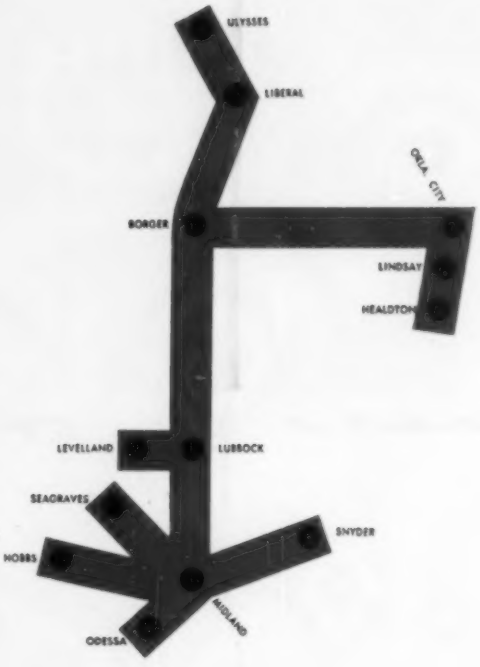
the Western Trail



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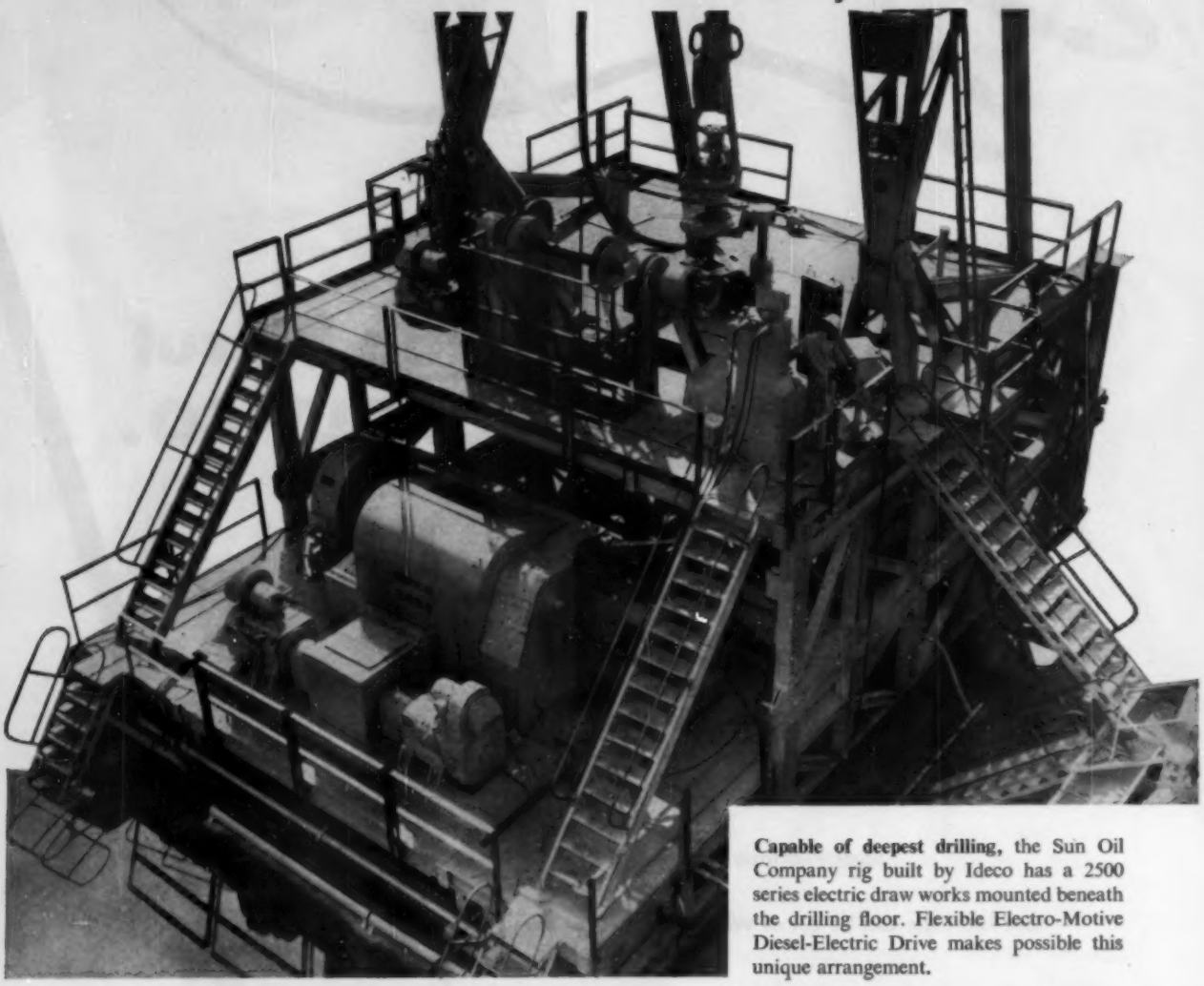
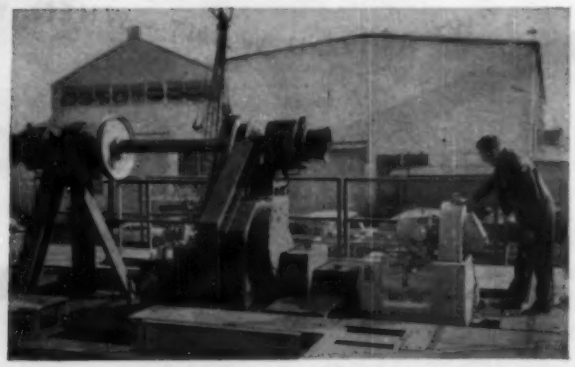


Capable of deepest drilling, the Sun Oil Company rig built by Ideco has a 2500 series electric draw works mounted beneath the drilling floor. Flexible Electro-Motive Diesel-Electric Drive makes possible this unique arrangement.

B. H. Hefner, Chief Electrical Engineer of Electro-Motive Division (center), discusses application of GM Diesel-Electric Drive with "Buck" Wilder of Sun Oil Company (left) and W. O. Cook, Vice-President of Ideco.



Newell B. Collins, Electro-Motive Service Engineer, inspects arrangement of drilling platform, where only one motor is mounted to drive rotary table and cathead.

flexible rig in sight

Sun Oil Company's new Ideco rig with Electro-Motive Diesel-Electric Drive takes the draw works off the drilling floor

Innovation in deep-well drilling rigs is the new unit built for Sun Oil Company by Ideco, one of the Dresser Industries, at its plant in Beaumont, Texas.

Powered by a pair of Electro-Motive SR-8 Diesel-Electric generator sets driving 7 motors, this revolutionary rig offers entirely new standards of flexibility, efficiency and economy.

Only one motor, powering the rotary table and cathead, is mounted on the platform. The Ideco 2500 series electric draw works is located beneath. This design avoids clutter, saves space and makes the rig easier and more economical to move.

Electro-Motive Drilling Rig Power Plants can be used with *any* drilling equipment operating today. The motors driving draw works, rotary table and mud pumps are connected by flexible cable to the generating units—and the connections can be made by anyone with a simple understanding of house lighting.

But to make doubly sure the equipment is properly used, we instruct your people both on the job and at our Factory Training Center in La Grange.

For further information about this moneysaving Diesel-Electric power, call your nearest Electro-Motive Representative.

Features of Electro-Motive Drilling Rig Power

Completely Integrated Design—Each of the major components designed and built to work together—*one* manufacturer—*one* source of service responsibility.

Maximum Portability—All components on skids with weight reduced to a minimum. Units are ruggedly built to withstand handling. No position problem—slashes setup and moving time on land rigs.

Unmatched Flexibility—At a flick of the selector switch on the driller's control panel, power can be selected from one or more generators to meet any power requirement.

Simplified Control—Centralized position of all controls for driller's convenience—continuously variable draw works speed control and complete rotary table torque control at the driller's finger tips.

Lower Drilling Costs—Lower first cost and lower cost per well drilled. Smooth electric power—flexible control—means less down time, speeds drilling.

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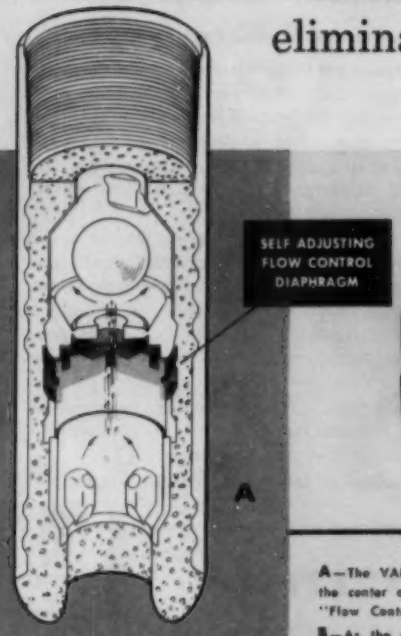
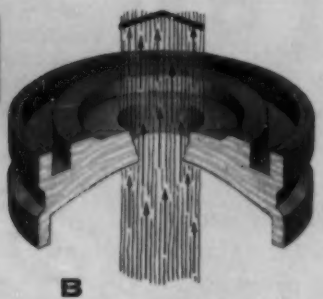
Compact electrical control cabinet utilizes proved components of General Motors Diesel-Electric locomotives. In photo are W. O. Cook, Bert Hefner, Bill Withers, Sun Oil Company, "Buck" Wilder, Sun Oil Company, and A. R. McLerran, Ideco.

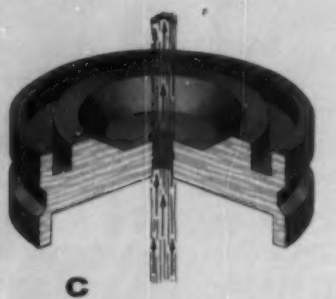
Driller's control stand is located on corner of the floor. Control panel carries selector switch, engine speed, mud pump, hoist and rotary table controls, as well as warning lights and safety switches.

See for yourself...

how the variable valve in FLEXIFLOW Shoes and Collars automatically fills the casing and eliminates destructive pressure surges



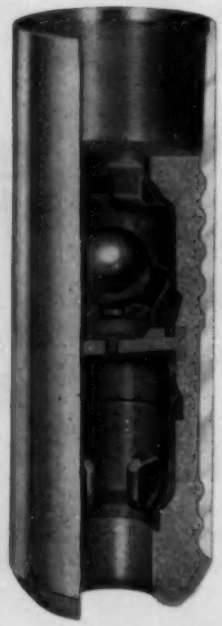




A—The VARIABLE VALVE consists of a small hole in the center of a reinforced synthetic rubber disc called "Flow Control Diaphragm"; see view at left

B—As the casing is lowered, pressure from below is exerted on the diaphragm and causes the hole to open up (see B) and a sufficient volume of fluid enters the casing to prevent a build-up of destructive pressure surges

C—As the rate of lowering the casing is lessened (just prior to setting the joint in the slips) differential pressure from below decreases and permits the Flow Control Diaphragm to contract, thus causing the hole to return to its smallest diameter (C). The reduced volume of fluid entering the casing prevents overfill.



Baker
FLEXIFLOW FILL-UP Shoe
Product No. 160

When casing equipped with FLEXIFLOW Shoes or Collars is lowered in the well, increase in pressure from below causes the variable valve to open up wider to relieve pressure from below by permitting a large volume of fluid to enter the casing. When downward movement of the casing is slowed down, pressure from below is reduced and the hole in the diaphragm contracts to restrict the fluid entry and prevent overfilling. This action of the variable valve in opening wider and closing down, synchronizes the rate of fill of the casing with the rate of lowering the casing, *and in so doing provides maximum relief from pressure surges.*

CUTS RUNNING TIME ONE-THIRD — Baker FLEXIFLOW Shoes and Collars can safely reduce casing running time by as much as one-third, because . . . they completely eliminate time-wasting surface filling of casing; and they permit the casing to be run faster due to the automatic "fill" from the bottom that eliminates possible damage to the formation from high-pressure surges.

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There's a Baker representative near you ready to explain the application of FLEXIFLOW Shoes and Collars and the part they play in Baker "Protective" Cementing.

For better Primary Cementing
Baker Flexiflow Fill-Up Collars and Shoes
Baker Casing Centralizers
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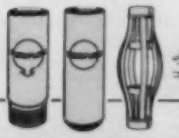

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EXCLUSIVE

Deep Well Fracturing In Headlee Devonian

"Results of Fourteen 75,000 Gallon Fracture-Type Treatments Show Profit"

H. D. Hansen
British American Oil Producing Company

W. L. Tinslar
Texas Gulf Producing Company

H. E. Wendt
Tidewater Oil Company

LARGE-volume, deep-well fracturing has given operators in the sprawling Headlee and Roberts Trend of West Texas a new lease on life. Prior to the first "super frac" treatment, numerous methods of stimulation were attempted in the "tight" Devonian lime with disappointing results.

On May 27, 1955, Tidewater Oil Company treated its No. 5 McKnight with 75,000 gal of refined oil and 75,000 lb of sand down 5½ in. OD casing. In eight months following this first job, operators have given 13 additional wells the 75,000-gal treatment.

Injection rates ranging as high as 33 BPM have been experienced. Treatments have been down 5½-in. OD and 7-in. OD casing. Injection pressures averaging near 5000 psi are common. Completions from open hole and from casing perforations are being fractured with equal success.

History. The Headlee field is located in eastern Ector County and western Midland County in the Permian Basin of West Texas, approximately four miles northeast of the city of Odessa.

The discovery well in the field was Texas Gulf Producing Company's E. V. Headlee No. 1, which was completed in January, 1953, in the prolific Ellenburger pay. This strike set off a very active drilling program, which is still in progress. To-date, four producing horizons have been revealed in the field, the Ellenburger at approximately 13,200 ft, which has proved to be by far the most productive, the Devonian at 11,800 ft, which will be discussed later, and the Strawn and Bend at approximately 10,000 ft, which are Pennsylvanian in age. There are now 79 producing wells in the field, of which 48 are producing from the Ellenburger, 24 from the Devonian, 6 from the Strawn, and 1 from the Bend.

Possibility of Devonian production in this area was first indicated in drill stem tests and logs of the early Ellenburger wells. The initial well to be completed in the Devonian pay was Texas

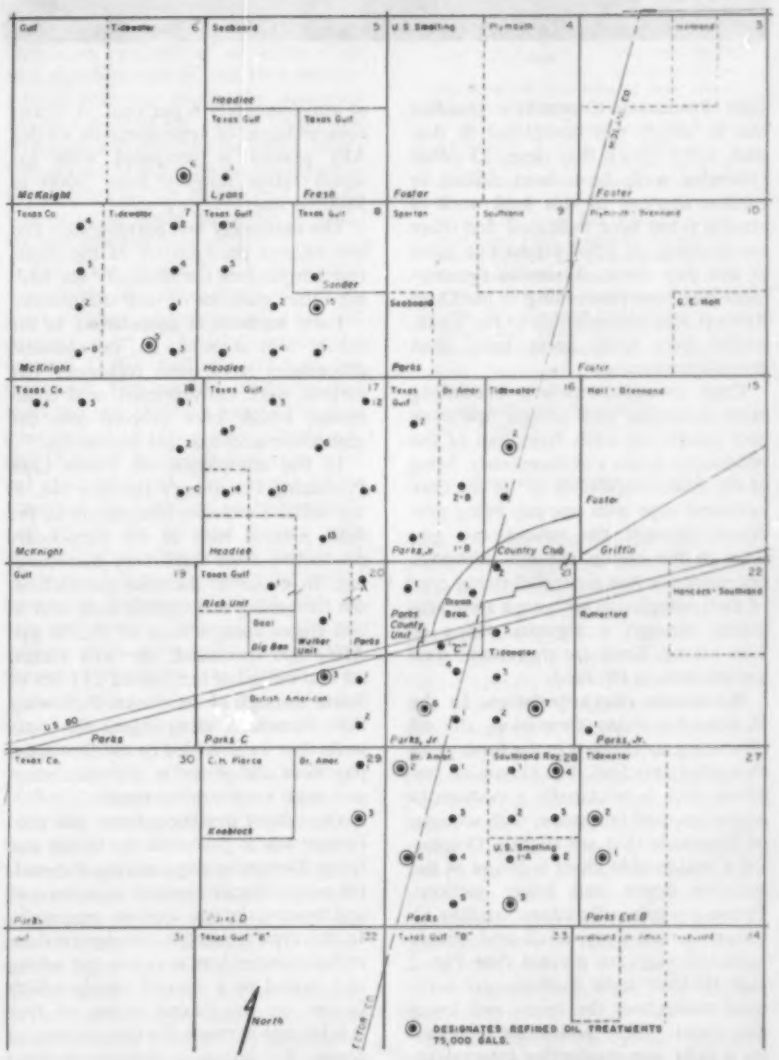


FIG. 1. Map of the Headlee multi-pay field, eastern Ector and western Midland County, Texas, showing the location of 14 wells given 75,000-gal fracture treatments.

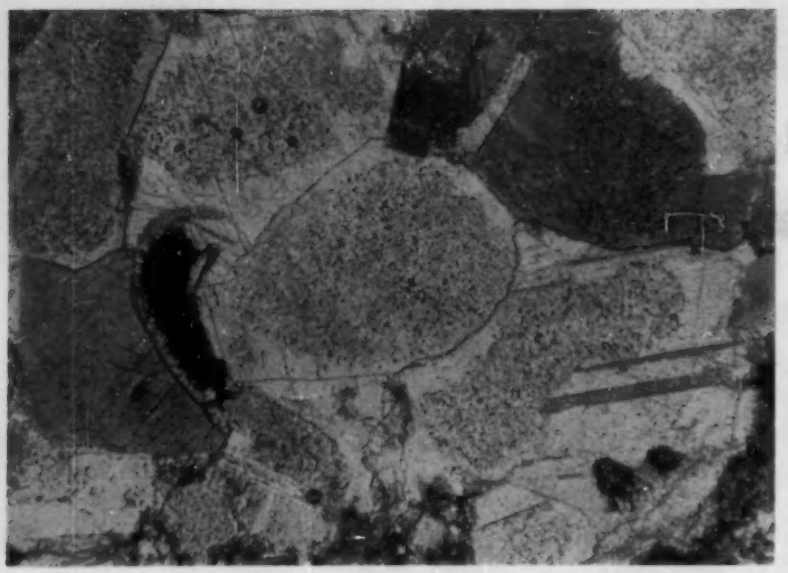
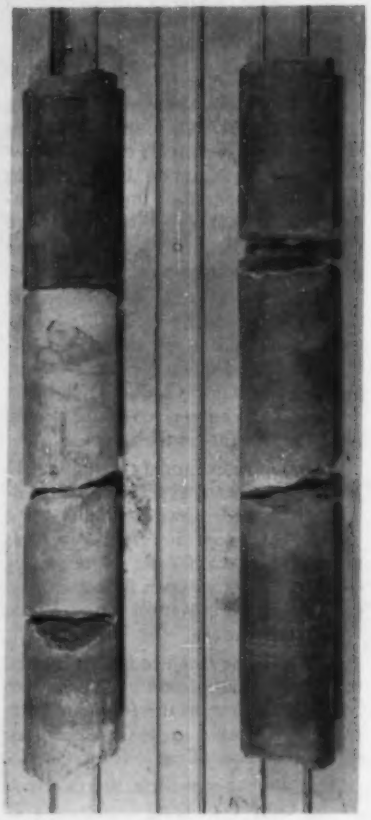


FIG. 2. Thin section photo-micrograph of the Middle Devonian Reservoir Rock (X 69).

FIG. 3. Typical Headlee Devonian core.



Gulf Producing Company's Headlee No. 4, which was completed in August, 1953. Since that time, 23 other Devonian wells have been drilled in various sections of this field until at present it has been indicated that there are in excess of 6500 productive acres in this pay alone. A similar development has been proceeding in the Dora Roberts area immediately to the south, where over 4400 acres have been proved productive.

Dual completions are becoming more common, with several operators now producing wells from two of the productive zones simultaneously. Most of the dual completions are of the conventional type with one pay being produced through the tubing and one through the casing annulus, although one operator has a parallel-string type of dual completion with each zone produced through a separate string of 2-in. tubing. There are at present 9 dual completions in the field.

Reservoir characteristics. In the Headlee-Devonian formation, the oil producing structure is in the form of an elongated anticline. The Devonian reservoir rock is principally a medium to coarse grained limestone, with sections of limestone that are slightly Dolomitic. Considerable chert is found in the extreme upper and lower sections. Porosity is primarily intercrystalline although a few very small and widely scattered vugs are present (See Fig. 2 and 3). Very tight fractures are common throughout the upper and lower pay zones. These zones are separated by a tight non-productive interval approximately 25 ft thick.

Average permeability in the pay section is less than 1.0 md with porosity of approximately 6 per cent. A straw-colored liquid of approximately 49 deg API gravity is produced with gas liquid ratios ranging from 3000 to 3800 to one.

The extremely low permeability and low natural productivity of the reservoir emphasizes the necessity for finding better methods of well stimulation.

Early methods of stimulation. In the earlier well stimulations, two general procedures have been followed. The earliest were conventional acid treatments, which later evolved into the multistage acid-base gel treatments.

In the completion of Texas Gulf Producing Company's Headlee No. 4, the initial Devonian completion in the field, natural tests of the supposedly productive zone were very discouraging. In order to increase production, the formation was treated with acid in two stages using a total of 13,500 gal. After this treatment, the well kicked off and on initial test flowed 211 bbl of liquid through ¼-in. choke. Following this successful completion, the next wells that were drilled to the Devonian pay were completed in a similar manner, with very similar results.

One slight deviation from this procedure was to perforate the upper and lower Devonian pays leaving the middle nonproductive section unperforated and treating the two sections separately. In this type treatment, an electrical interface control tool is run in the tubing and seated in a special nipple which is run on the tubing string so that it is located between the two perforated zones. By using a non-conductive inert gel solution to block one zone, the other may be treated with acid, which of course, is electrically conductive. When used in this manner, the interface may be kept at the control tool by watching a signal at the surface and pumping on the tubing or casing, thus forcing the acid into the desired perforations. This method of treatment, while interesting, proved to be no more successful than the conventional acid jobs in increasing the productivity of the Devonian wells, and operators continued searching for something more satisfactory for sustained well production.

Fracture-type treatments had been in use in various areas of the Permian Basin to increase oil production, but usually in wells of less than 8000-ft depths and volumes in the range of 20,000 gal. The first attempt at a fracture-type treatment in the Headlee-Devonian was with 10,000 gal of an acid-

base gel. This job, in which the well was treated down tubing, was only partially successful in that the formation sanded up as the oil flush was completed and it was impossible to overflush as originally planned. From the experience gained on this treatment and the previous acid treatments, a revised fracturing program was formulated as follows:

1. Wash formation with 500 gal of mud acid.

2. Treat formation down 2½-in. tubing with 1000 gal of acid immediately followed by 3000 gal of an acid-emulsion type of fracturing agent with 1 lb of sand per gallon.

If this stage of the treatment performed satisfactorily, allow well to clean up and proceed into the third stage as follows:

3. Treat formation down 2½-in. tubing with 30,000 gal of the acid-emulsion type fracturing agent with 1 lb of sand, flush with lease oil and overflush with 60 to 80 bbl of lease oil.

Two variations of this general procedure have been used in the field. One of these was pumping the fracturing fluid down the tubing-casing annulus while the second was pumping the same fluid down the annulus and tubing simultaneously. Both of these variations have resulted in treatments that are equally as satisfactory as the original with only slight increases in injection rate. A total of 3 wells have been treated by this method in this area.

Results of these treatments have been very encouraging, especially when compared to the performance of the acidized wells in the field. For this reason, operators began to look into the feasibility of using even greater volumes of fracturing fluid and higher injection rates.

Number of jobs	14
Volume refined oil	75,000 gal
Amount of sand	75,000 lb
Injection rate	28.4 BPM
Injection pressure	4705 psi
Maximum pressure	4965 psi
Depth of treated interval	11,910 ft
Footage open for production	142 ft
Completion method:	
Number open hole	11
Number casing perforations	3
Size of casing:	
Number down 5½ in. OD	13
Number down 7 in. OD	1
Mesh of sand	20-40
Amount of flush	285 bbl
Type of flush	9-10 lb/gal salt water
Pumping equipment:	
Total hydraulic hp used	4940
Number of pumps	19
Number of trucks	10
Treatment cost	$16,175

FIG. 4. Tabulation of average treating data, for 14 75,000-gal fracture treatments, Headlee Devonian field.

First Big 'Frac' Job

Tidewater Oil Company's No. 5 McKnight was given the first 75,000-gal fracture treatment in the Headlee field on May 27, 1955. Several factors prompted Tide Water to attempt this large-volume "frac" treatment.

As it has been pointed out, extremely low permeabilities are characteristic of the massive Devonian pay section in the Headlee field. Little reservoir fluid is recovered by natural drill stem testing of the Devonian zone. Low well productivities and rapid production declines were experienced on early wells that were stimulated by acid treatment. Operators realized at an early stage that development of the Headlee-Devonian reservoir would be restricted unless a method for greatly improving well productivity could be found. Injection pressures experienced during acidizing supported the feeling that the Devonian zone could be given a high-volume fracture treatment.

The Tide Water No. 5 McKnight was drilled to a total depth of 12,020 ft. A production string of 5½-in. OD casing was set at 11,910 ft, leaving the interval 11,910 to 12,020 ft open for treatment. The fracture treatment was executed out in two phases. The first consisted of 10,000 gal of "refined oil" and 10,000 lb of sand flushed with 6000 gal of treating oil. The second phase consisted of 65,000 gal of "refined oil" and 65,000 lbs of sand flushed with 4000 gal of treating oil and 250 bbl of salt water. Injection pressure during the treatment averaged 4700 psi with an average injection rate of 27 bbl per minute. Actual pumping time during the entire operation was 92 min.

No production test was taken on the No. 5 McKnight prior to the 75,000-gal treatment. On potential test after recovering the "refined oil," the No. 5 McKnight flowed 588 bbl per day on a 14/64-in. choke with a tubing pressure of 2345 psi.

Well preparation. One outgrowth of high-volume, high-pressure fracture treatments in the Headlee field has been a change in the design of casing strings. Most operators prefer a 5½-in. OD production string for completion in the 12,000-ft Devonian zone. Casing programs on most wells completed prior to the "big frac" treatments called for use of 5000 ft of 5½-in. OD, J-55, 17-lb per ft pipe in the midsection of production strings. Maximum injection pressures on the 75,000-gal treatments range between 5000 and 6000 psi. Standard practice in the field now is to run a full production string of grade N-80, 5½-in. OD casing.

As previously mentioned, the Devonian section in the Headlee field has two productive zones separated by a dense interval. A 7⅞-in. hole is drilled to a total depth at the base of the lower Devonian productive zone. Most operators prefer open-hole completions, in which case 5½-in. OD production string is set in the dense interval separating the two productive zones. This leaves the lower Devonian zone open for fracture treatment. In some cases, operators plan to selectively treat the upper Devonian at a later date with 75,000 gal of "refined oil" and 75,000 lb of sand.

Before drilling the casing shoe, the production casing string is tested to 6000 psi internal pressure. Preparatory to coming out of the hole with the drill string for the large volume "frac" treat-

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A 1950 petroleum engineering graduate of Texas A&M College, W. L. Tinslar has been a petroleum engineer in Midland for Texas Gulf Producing Company since 1953. Previously, he was employed by Gulf Oil Corporation in West Texas for three years.

Now a district engineer for Tidewater Oil Company at Midland, H. E. Wendt has been working for Tide Water in the Permian Basin area of West Texas and New Mexico since 1949. He was graduated in 1949 from Texas A&M with BS degrees in petroleum engineering and mechanical engineering.

FIG. 5. Aerial photograph showing the arrangement of fracturing equipment used in treating Headlee Devonian wells with 75,000 gal

ment, the hole is circulated with either lease crude or "refined oil." The tankage necessary for storage of treating oil and salt water flush are moved to the well site. The surface pumping equipment, sand-oil blenders, and other accessory equipment are then moved to location and connected.

Treatment procedure. Immediately after getting the bit and drill pipe out of the hole, a heavy-duty wellhead fracturing manifold is flanged above the blow-out preventer. The especially designed manifold has twelve 2-in. outlets into which high-pressure lines from the pumping equipment are connected, as illustrated in Fig. 6. A high-pressure gate valve and a check valve are located near the wellhead in each line that is tied into the manifold. Surface lines between the pumps and wellhead fracturing manifold are tested for leaks with 7000 psi pressure.

The Devonian formation is broken down with 5000 gal of treating oil. The zone usually breaks down with from 3500 to 4500 psi surface pressure. A practice that was used on the first fractured wells, but abandoned later, was to mix a pilot treatment of 10,000 gal of "refined oil" and 10,000 lb of sand. After flush, this was followed by the remaining 65,000 gal of treating oil and 65,000 lb of sand.

Overall average injection rate on 14 large-volume fracture treatments completed in the Headlee field has been 28.4 bbl per minute. The injection pressure experienced during treatment has averaged 4705 psi, while the maximum treating pressure has averaged 4965 psi. The average footage open for

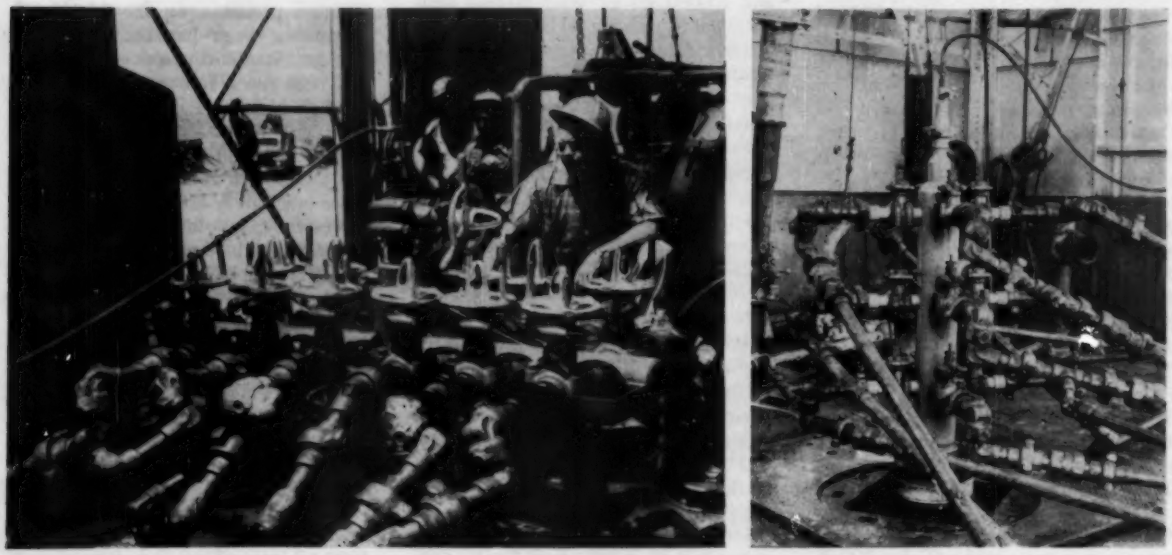


FIG. 6. Two types of wellhead fracturing manifolds used in fracturing Headlee Devonian wells with 75,000 gal of refined oil and 75,000 lb of sand.

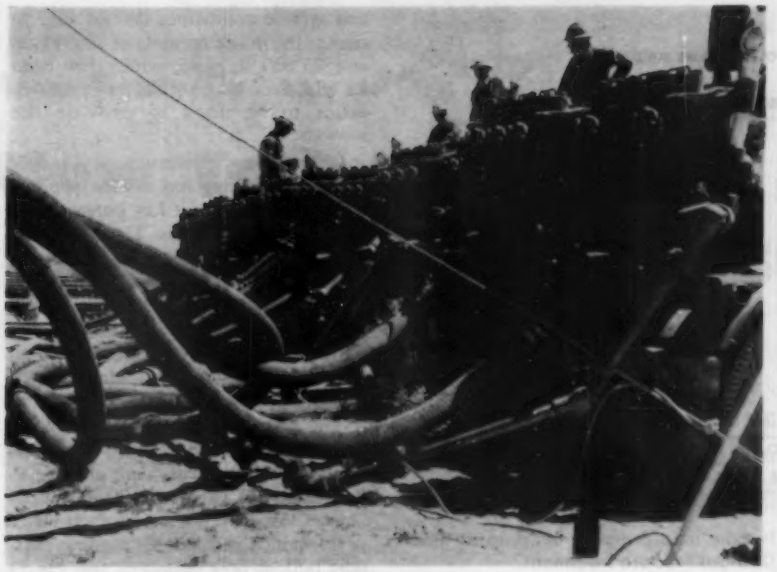


FIG. 7. Group of 3600-hp pumps. Two of these groups are used on 75,000-gal fracture treatments.

treatment has been 142 ft and the average depth of the treated interval on the 14 wells has been 11,910 ft.

The "frac" treatment is flushed with from 250 to 275 bbl of 10 lb per gallon salt water. A salt water flush is necessary to overcome 5300 psi of reservoir pressure while running tubing in the hole for completion. Experience on the fourteen 75,000-gal treatments shows there is seldom more than 15 ft of sand fill-up in the hole after treatment. After the tubing string has been run, the wells are swabbed to flowing and the refined oil recovered preparatory to taking a potential test.

Fracturing equipment. To perform the 75,000-gal fracture treatment, pumping equipment is set up in two independent units. Each unit is equipped with a separate sand-oil blender. Sufficient horsepower is provided in each unit to displace 15 bbl of fluid per minute against 5000 psi wellhead pressure.

The distance the pumping equipment is located from the wellhead is governed by two factors. From a safety viewpoint, the pumps must be located far enough from the wellhead and drilling rig to reduce the fire hazard. On the other hand, if the pumps are located too far from the wellhead, a considerable amount of hydraulic horsepower is required to overcome surface line friction. The distance between pumps and wellhead for Headlee fracturing operations is usually about 200 ft.

Six skid-mounted tanks are required to provide storage for 2000 bbl of "refined oil" and 275 bbl of salt water flush needed on each 75,000-gal job. Three tanks are tied into each of the two blending-pumping units. The tank discharges are paralleled and connected into the blending unit. Four bulk sand trucks, two for each group of pumps, are required to transport the 75,000 lb of sand used for treatment. During the fracturing operation, bulk sand and treating oil are supplied the blending and proportioning trucks in desired quantities. The two materials are mixed in a ratio of 1 lb of sand per gallon of oil. The mixture is furnished to each pumping unit through a separate suction hose from the blender.

It is estimated that the average large-volume "frac" treatment in the Headlee field requires 5000 hydraulic horsepower. On jobs where standby pumping is furnished, as much as 7200 pump horsepower has been set up for use on the location. At least one fire truck is present on each 75,000-gal job.

A 20-40 mesh Ottawa sand has been used on most of the treatments performed thus far in the Headlee Devonian field. Refined oil has been used as a carrying agent on all 14 of the 75,000,-gal treatments. Two types have been used for the treatments, the primary difference being in API gravity. The gravity range for one type of "refined oil" used is from 7 deg to 11 deg API while the second type has an API gravity range from 20 deg to 24 deg. The sand settling rate and API fluid loss properties of the two types of "refined oil" are similar.

Average total treatment cost for Headlee 75,000-gal jobs has been $16,-175. Materials used in the average treatment will cost approximately $10,-500, of which about $5800 is returned by sale of the recovered treating oil. The charge for pumping equipment will average about $4000, whereas tank rental, blenders, and miscellaneous charges will total near $1700.

Results. Today the standard completion for the Devonian wells of all operators in the Headlee field is the large-volume fracture treatment. This rapid adoption of the "super frac," which was developed in May, 1955, best describes the value of this new tool. Seldom has any completion method been applied to general usage in one field so quickly.

On one of the early tests of the Tidewater McKnight No. 5, first large volume fractured well, it produced at the rate of 140 bbl per day, no water, on a 8/64-in. choke with a tubing pressure of 2630 psi. Seven months later in February, 1956, a test showed a rate of 126 bbl per day with no water on the same size choke with a tubing pressure of 2575 psi. Although these tests are an indication of the success of the fracture jobs, they cannot tell the whole story. The capacity of each fractured well far exceeds the prorated allowable, and all wells are penalized for having gas-liquid ratios above 2000/1. Because of these restrictions, it may be several years before an accurate evaluation by well performance can be placed on the fracture jobs.

To more completely present a comparison of the results of the different

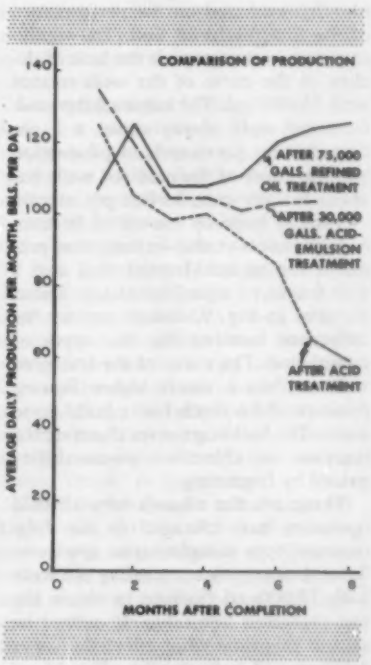


FIG. 8. Graph showing a comparison of production performance of wells after three methods of well stimulation in the Headlee Devonian field.

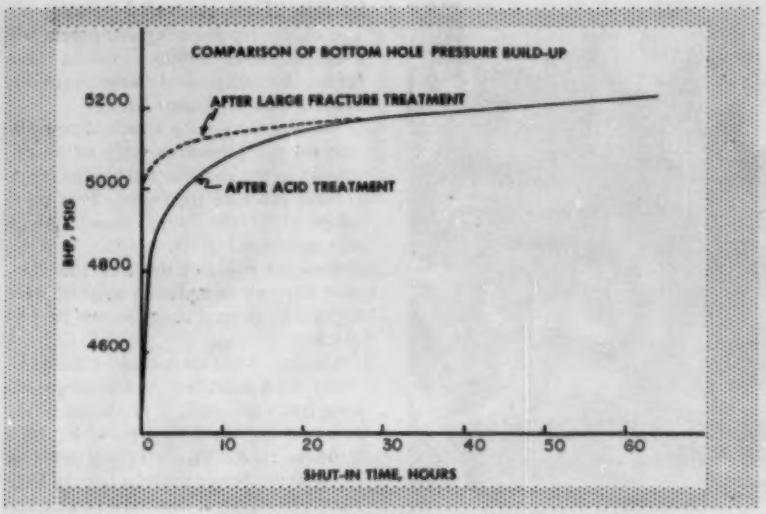


FIG. 9. Curve showing a comparison of bottom hole pressure build-up vs time of an acidized well and a well given a 75,000-gal fracture treatment.

types of well completions, a graph of average daily production rate vs time is included in Fig. 8. For all practical purposes, the initial production rates of all three stimulation methods, namely acid, acid-emulsion fracture and "super" fracture, are equal. The slight variation is due to structural position and differences in gas-liquid ratios of the wells. The curve of the 75,000-gal fractured wells is believed to be representative even though the last four months are based on the performance of the first fractured well. The significant fact in this graph is the lack of decline in the curve of the wells treated with 75,000 gal. The curve of the acid-fractured wells shows about a 2 per cent decline per month in production and the curve of the acidized wells has about 9.5 per cent decline per month.

Typical build-up curves of bottom-hole pressures vs shut-in time were prepared for an acid-treated well and a well fractured with 75,000 gal. These, pictured in Fig. 9, clearly portray the difference between the two types of completion. The curve of the fractured well exhibits a much higher flowing pressure and a much faster build up to static. The build-up curves illustrate the increase in effective permeability gained by fracturing.

These are the reasons why all field operators have changed to the "big-fracture" type completion on new wells. Several operators are treating old wells with 75,000-gal fracture to obtain the top proration allowable. It cannot be said at this time what effect the super fracture will have on the ultimate recovery, but these large fracture treatments have greatly improved the present productivity of the wells.

Future. The future of large-volume fracturing in the Headlee-Devonian is assured by the excellent success on the 14 treated wells. Much effort is being made by operators and service companies to reduce the cost to permit a wider usage of this new tool. Any major reduction in cost appears unlikely without changing the basic procedure. The high productivity indices of these fractured wells, which range from 0.8 to 3.5 B/D/psi, are the probable reason why no immediate changes will be made.

Field personnel, engineers, and supervisors are asking themselves many questions. What about increasing the job to 200,000 gal of oil and 200,000 lb sand? What would be the effect of changing the sand/oil ratio to 2 lb per gal or varying the grain of the sand? Why not use a different type of carrying agent such as salt water or lease crude, or use additives to reduce the fluid loss or increase the sand carrying ability? These are just a few which only the future will answer. Most operators and service companies do not care to change the magic formula of 75,000 gal and 75,000 lb sand, which has been so effective. Much field research remains to be done to provide the answers.

Other areas. Undoubtedly, large-volume fracturing has a wide application in most areas of low permeability with thick pay sections. The large fracture-type of stimulation has been tried on one well outside of the Headlee field recently. The super fracture fits several pays of the Permian Basin, and it will undoubtedly find wide application in other parts of the world where conditions are similar.

The operators of the Headlee have many questions concerning the wells treated to date. Surveys are planned to determine the extent of the fractured zone. Close observation of each well's performance is made by running periodic bottom hole pressures and gas-oil ratio surveys. Any early change in producing characteristics are of vital importance to help determine what to do to increase the effectiveness of the fracturing.

The super fracture of today is one of the new tools developed recently to help eliminate part of the dry holes and some of the uneconomical wells of the past. Further development and research of fracturing will help to continue this advancement.

Acknowledgments

The writers wish to express their appreciation to the managements of British American Oil Producing Company, Texas Gulf Producing Company and Tidewater Oil Company for permission to publish the data herein. In addition, the authors gratefully acknowledge the cooperation and assistance of Dowell, Inc., Halliburton Oil Well Cementing Company, and Core Laboratories, Inc. Special acknowledgement is extended to Dr. W. A. Waldschmidt for thin section data and photograph. * * *

New Record Set in Gun Perforating

A new world's record in the number of shots fired in one well has been claimed by McCullough service crews who shattered their own record when they recently shot 9738 perforations through 7-in. 29-lb N-80 casing. Deepest interval perforated was 9504 ft.

The well started flowing after perforating began and made 1700 bbl of oil during the perforating job which took five days and nights to accomplish. An average of 83 bullets were fired per hour during that interval. A blowout preventer had to be used to keep the well under control.

McCullough's first gun perforating world record was set in December of 1946 when 4980 holes were shot in one well in 78½ hours.

EXCLUSIVE

Some Timely Tips on . . .

How To Interpret TUBING CALIPER SURVEYS

Some basic principles you can apply to get the full story from caliper charts.

Jack T. Martin
The Texas Company, New Iberia, La.

CORROSIVE action in the tubing of oil and gas wells has become a recognized major economic problem. Its importance has been even more noticeable during recent times when the supply of tubular goods has been limited. To know the location and severity of corrosion damage in tubing is a requirement to cope properly with the problem. It is apparent that in order to obtain the information desired, there is a need for some means to chart and measure the results and location of interior tubular deterioration without killing a well and pulling the tubing for surface inspection. The mechanical tubing caliper instrument can be employed to fulfill such a requirement. The instrument is entirely mechanical, and is run into the tubing on a steel measuring line similar to the way subsurface pressure equipment is handled.

If a well is to be worked over, and severe corrosion of the tubing is suspected, it is desirable to have a tubing caliper survey run to determine if a fishing job might be expected. If severe corrosion is indicated by the caliper survey, a fishing job can sometimes be prevented by taking proper precautions. On the other hand, if the caliper charts indicate the tubing is in excellent condition, then unnecessary rig time will not be required in removing the tubing and in handling it with care. If the caliper survey is used to cull the worst joints of tubing, a future tubing failure and fishing job can be averted. When time is of the essence, it is possible to make field interpretations of the original charts as soon as the instrument is removed from the well. Nevertheless, the interpretations have a greater degree of accuracy when time allows a complete study with a report made at a later date.

Influence of instrument design. The tubing caliper instrument mechanism has changed with improvements that have been incorporated into the instrument. One of the design changes is in the shape of the feelers, while another is the spacing and number of feelers. If some feelers come more to a point and are closer together, they are able to pick up smaller pits to a deeper depth in the wall of the tubing. Nevertheless, the instrument with the more blunt end feelers is not so likely to cause damage to the tubing. The various spring tensions used to hold the feelers against the wall of the tubing also have an influence on the recordings obtained and possible damage to the tubing.

These and other variations bring about several considerations when interpreting the tubing caliper survey charts. One type of feeler with a certain spring tension will have a tendency to maximize corrosion pits while another type will minimize them. Another factor that should often be considered when interpreting the charts is that magnification or reduction of the original recorded chart has a tendency to reduce errors and create errors. Hence, to determine the more accurate rate of corrosion from tubing caliper charts and surveys, the instrument with the same shape feelers and spring tension should be used in any well for the life of a particular string of tubing. If this is not done, the result is a combination of corrosion rate and difference in measurement induced by using different designed instruments.

Some instruments in the past have used wheel type feelers, then changed to feeler sled points, and some instruments now have a ball point feeler. Naturally, the feeler wheels had a tendency to ride over the deposition on the walls of the tubing, while the pointed feelers had the ability to scratch loose and measure underneath any scale or deposition. Thus, it can easily be seen how a caliper survey, before a change in design, and another afterward in the same tubing may indicate a high rate of corrosion, which may actually be the result of an improvement in the instrument's accuracy, plus the corrosion rate.

Surveying coated tubing. When calipering an internal plastic coated string of tubing, it has been found advantageous to use special feelers that do not have a tendency to disturb and destroy the coating. The old wheel type feeler and a ball pointed feeler are desirable for such calipering. It has been found that the knurled drive wheel can disturb a special coating inside a tubing string. In any case, the fewer times the calipering instrument or any other wire line equipment is run inside plastic coated tubing, the better possibility the coating has of staying intact, since a wire line may cut through the coating at any "crook" in the tubing.

Chart correlation. In calculating and determining the rate of corrosion from two caliper surveys made at different dates, it is often necessary and of interest to correlate the two charts and observe the increase in pit depth of individual pits. To do this, it is of considerable value to note short joints, mill defects, etc., as guides or reference points. However, a particular joint may appear short on one chart and of standard length on another chart. This is

brought about by slippage of the instrument's driver wheel which is driven by contacting the wall of the tubing as the instrument is pulled up the string of tubing. Paraffin is often a contributing factor when slippage occurs. The pattern of the collar kick sequence for a series of tubing joints will usually form a sloping straight line if no slippage occurs provided the tubing string is made up of only one range of tubing. (See Fig. 3)

Interpretation of Charts

Consideration must be given to the fact that it is possible for the feeler points to pass on each side of a very small or narrow shaped pit or hole. This can happen on one survey while the feelers may pass through the middle of the same pit or hole on the next survey. When this happens in a reverse sequence, it indicates a reduction in pit depth which many times leads to a general discussion on the accuracy of tubing caliper surveys. The greater the number of feelers and the closer they are together, the less likely any isolated pits will miss detection. Thus, the tubing caliper instrument is not always effective in locating the source of a tubing leak. It has been offered as a suggestion that two instruments be run simultaneously, and that they be connected together so that the feelers of one instrument can caliper the area missed by the space between the feelers on the other instrument. The two charts together would then represent 360 deg of the internal tubing surface. It appears that the difficulty in performing such a dual survey lies in the fact that the total length of tools and instruments in the tubing would greatly enhance the prospect of losing and leaving the equipment in the tubing. The additional length of the extra instrument in the well could prevent satisfactory wire line recovery and the tubing might have to be pulled to recover the equipment.

Tubing in compression. In studying the caliper charts, it may sometimes be found that some lines between collar kicks curve or bow. (See Fig. 1.) Such a chart is characteristic of a tubing string in compression. Although the tubing may have been originally set in tension a difference in temperature of wash water and production fluid often accounts for a tubing string found to be in compression. The distance between the lines on the chart corresponds to a change in internal radius of the tubing. This is most obvious when evenly distributed corrosion or erosion is indicated (See Fig. 2.)

Mashed spots. In case there are several pits of varying depths at a certain depth in the tubing, only the deepest pit is recorded. A mashed upset or tubing body is recorded as a pit because the feelers are pressed inward on one side and permitted to move outward on the other side. However, the mashed place is indicated by smooth lined deflection and can be differentiated from the corrosion pits most of the time. (See Fig. 3.)

A downward kick of the stylus or an indication of a pit in reverse indicates a reduction in the tubing diameter which may be deposition, scale or smaller inside diameter tubing that is still within the mill and API tolerance. (See Fig. 4.)

Ringworm corrosion. Corrosion and

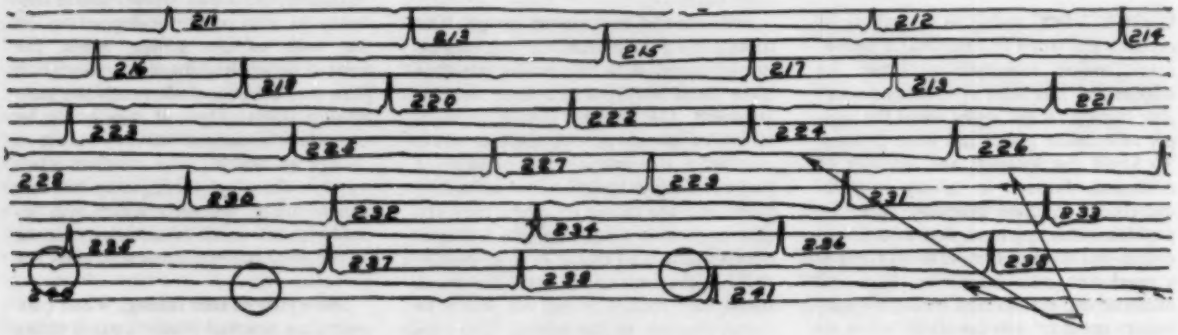


FIG. 1. **Tubing in compression** is indicated by the bowed chart line with a slight downward kick in the middle of each joint on 2⅞-in. tubing.

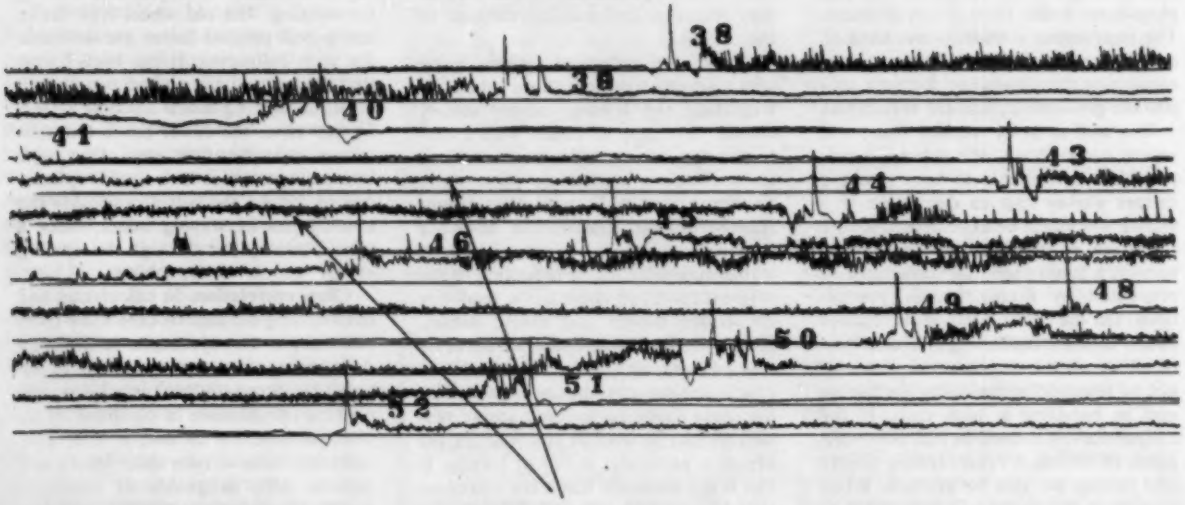


FIG. 2. **Severe case** of evenly distributed general corrosion in 2⅞-in. tubing is represented in joints 42 and 43.

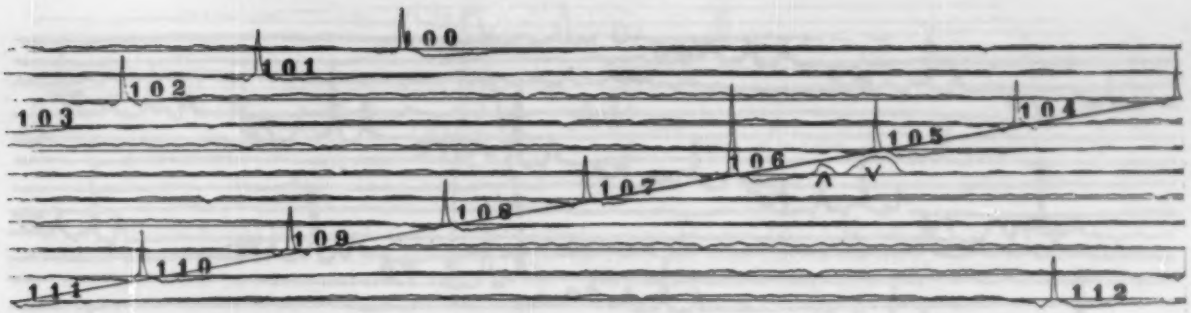


FIG. 3. **Severe external mash** is indicated in the upper end of joint 106. Note tubing sequence. A straight line drawn through each coupling indicates no loss in the linear scale due to drive wheel slippage.

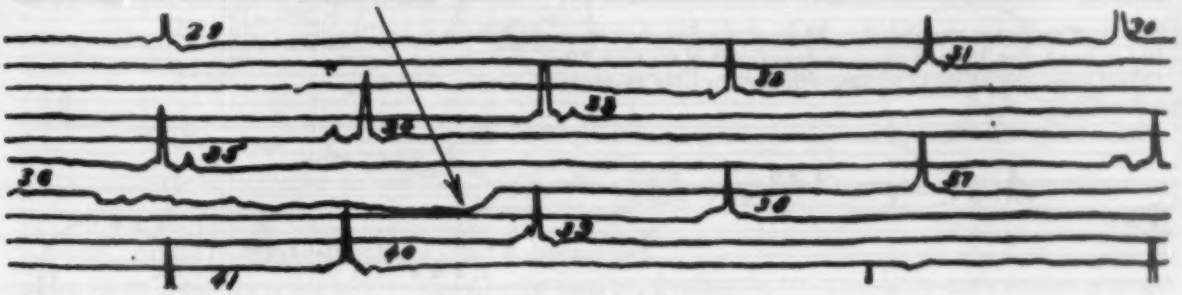


FIG. 4. **A deposition** could be the cause of the downward deflection in the middle of joint 36. This deflection represents a reduction in diameter.

erosion are generally made readily apparent by viewing the tubing caliper charts. Ringworm corrosion is one of the easiest types of corrosion to interpret from the charts. (See Fig. 5.) The deep pits are usually the same distance from the collar kicks in each string of tubing, and are generally at the beginning of the upset and not actually on the upset itself.

In some cases, this type of corrosion has been interpreted as being caused by mill defects, but on close examination it is usually borne out that mill defects are closer to the collar kicks and show a smoother rounded deflection than does ringworm corrosion.

Erosion and corrosion caused by restrictions in the tubing, such as a storm or pressure reduction choke, are frequently isolated and located immediately above where the choke was set or the restriction was located in the tubing string. (See Fig. 6.)

The depth of pits is usually measured in inches, but the amount of corrosion damage is sometimes expressed in percentage reduction of tubing wall thickness. (This is shown in Table 1.)

Additional Information From Charts

In order to obtain all the information possible from tubing caliper surveys, a review of the charts and interpretations prior to the removal of the tubing can be used to cull the tubing as it is pulled from the well. A limit in wall reduction of the tubing is often determined after considering among other factors, the time lapse from the last survey. Such culling makes it possible to classify tubing at the well location for further use. When classifying tubing as indicated by a caliper chart, it is important to note whether the number one joint is the first standard joint, or if it is a pup joint that is immediately below the Christmas tree hanger joint. To reduce further the possibility of an error, it is also of value to check the charts to insure that there have been no errors made in numbering the joints.

Other records obtained. It is possible to take advantage of tubing caliper survey charts which were made for corrosion determination, to check certain information in the well records. If the well had gas lift valves in it at the time of the survey, the location and sometimes the type of gas lift mandrels can be determined. In some areas, and under certain corrosive conditions, gas lift valve mandrels are found to have holes eroded or corroded in them after

TABLE 1. Reduction in wall thickness with pit depth for two tubing sizes.

Pit depth (inches)	Wall thickness percentage reduction for 2⅞" OD EUE tubing		Wall thickness percentage reduction for 2⅜" OD EUE tubing	
	Reduction in body (per cent)	Reduction in upset (per cent)	Reduction in body (per cent)	Reduction in upset (per cent)
0.03	14	9	16	10
0.04	19	12	21	11
0.05	23	15	26	17
0.06	28	18	32	20
0.07	32	22	37	23
0.08	37	25	42	27
0.09	42	28	47	30
0.10	46	31	53	33
0.11	51	34	58	37
0.12	55	37	63	40
0.13	60	40	68	43
0.14	65	43	74	47
0.15	69	46	79	50
0.16	74	49	84	53
0.17	79	52	90	57
0.18	83	55	95	60
0.19	88	58	100	63
0.20	92	61	—	67
0.21	96	64	—	—

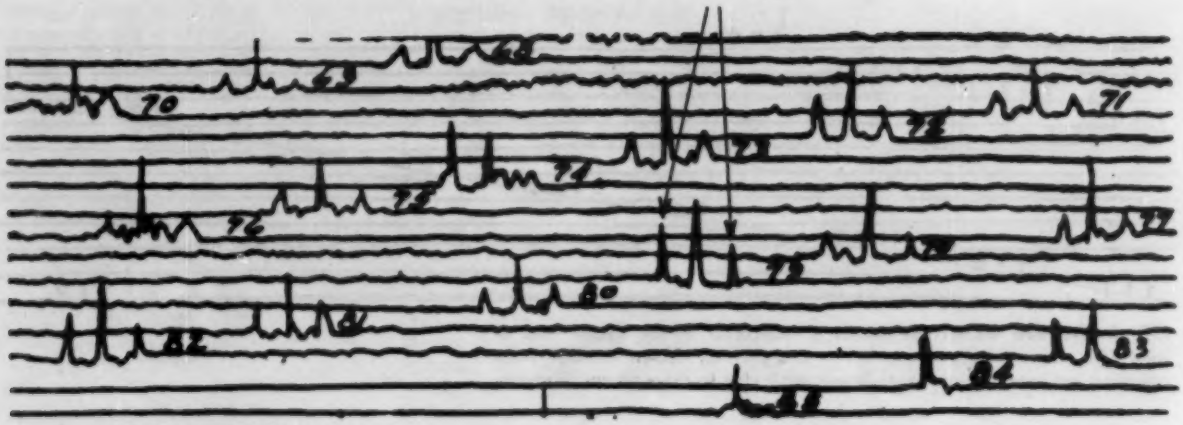


FIG. 5. **Ringworm corrosion** in 2⅞-in. EUE tubing in a low-pressure well producing 50 per cent water. There is complete penetration of the tubing wall at upper end of joint 74 and lower end of joint 78. Fishing operations were necessary to retrieve the tubing.

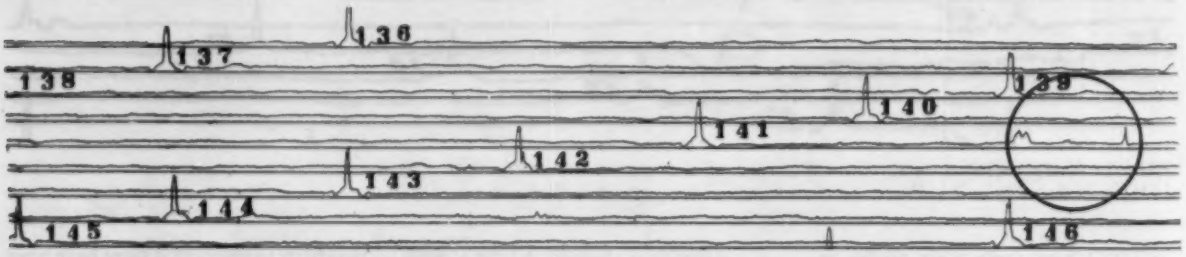


FIG. 6. **A pressure reducing choke** and storm choke brought on the corrosion at the upper end of joint 141.

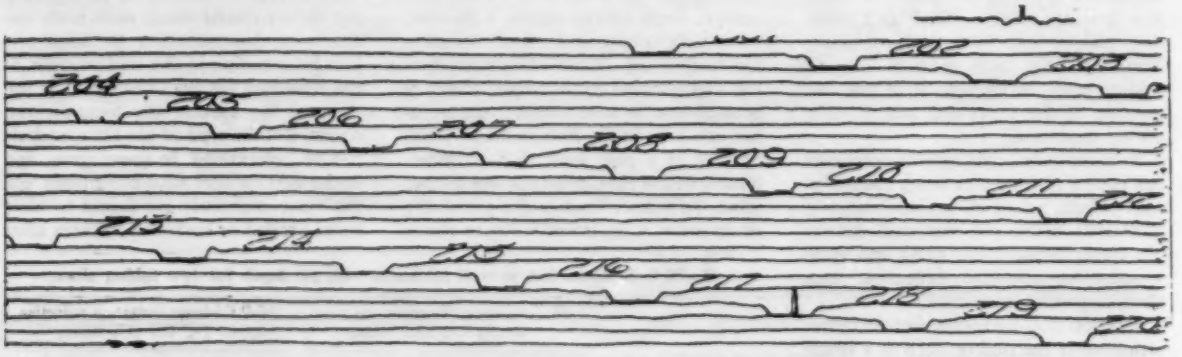


FIG. 7. **Caliper feeler movement** at connection in flush joint tubing.

FIG. 8. **Gas lift mandrels** (A and B) show no corrosion present. Note gas lift valve ports.

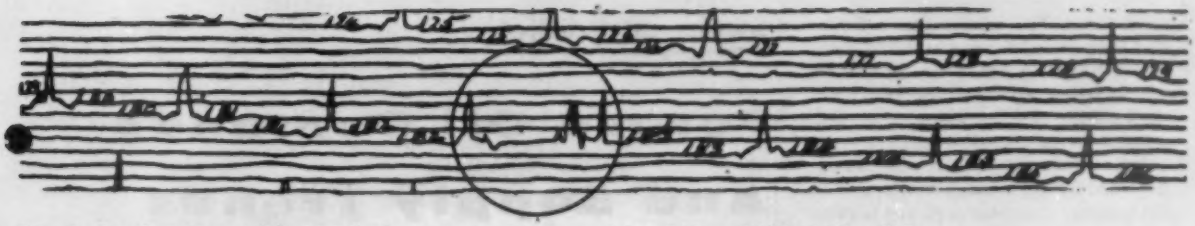


FIG. 9. **Erosion in gas lift mandrel** was located between joints 182 and 183. A ½ x ¾-in. hole had been eroded in the mandrel opposite the gas lift valve port from outside the tubing. A ¼ x ⅛-in. hole had been eroded from the inside slightly above and opposite the mandrel port. Deep corrosion pits were present opposite and just below the mandrel port.

FIG. 10. **Landing nipple** for pressure reduction and storm choke assembly is located between joints 169 and 170. It is shown circled.

having been in operation a certain number of years. A tubing caliper survey run periodically in such wells can determine, in most cases, the extent of damage to the mandrels and which gas lift wells are in need of remedial work to prevent a costly fishing job. (See Fig. 8 and 9.) The location of special nipples and safety joints in the tubing strings can also often be determined. (See Fig. 10.)

Tubing in pumping wells often has rod wear which is represented by irregular chart deflections (See Fig. 11). The length of the deflections is approximately the same as the pump stroke and the distance between the deflected tubing wear is proportioned to the length of the sucker rods.

Upset or flush joint coupled tubing joints are reflected by different chart line deflections. Tubing caliper charts of flush joint coupled tubing sometimes have an indicated pit at the middle of the coupling. The indicated pit may be the result of five reasons: (1) two types of flush joints coupled together; (2) two chamfered couplings made up together forming a "V"; (3) one bore diameter at a maximum tolerance with the other at a minimum tolerance; (4) two couplings having eccentric bore diameters to each other; and (5) the joints were not made up tight enough.

In the past, many charts have had erratic deflections of joint couplings. This is being overcome with each improvement of the caliper instruments. Better representation and interpretation of couplings will aid in future tubular corrosion surveys.

Instrument Effect of Corrosion

There have been some cases whereby corrosion was accelerated due to the removal of protective films by calipering instruments. This is especially possible in those cases where a scale results from the action of the produced effluents. The calipering instrument, no doubt, does not actually scrape any metal away, but the removal of scale which can be products of corrosion or mill scale, leaves the bright metal exposed to any corrosive effluents being produced. A galvanic cell can then be formed and with the acids that are present in corrosive wells, corrosion can be activated in the feeler or drive wheel tracks at a much greater rate than had previously been encountered. Some proprietary semipolar organic compounds used as corrosion inhibitors have the ability to remove scale and depositions. By treating the tubing with such a compound immediately following or preceding the tubing caliper survey, all the scale is removed from the wall of the tubing and a galvanic cell is less likely to form at the feeler or drive wheel tracks.

Status and Rate of Corrosion

The worth of tubing caliper surveys in determining the status and rate of corrosion is superior to either the coupon survey or the iron content of well

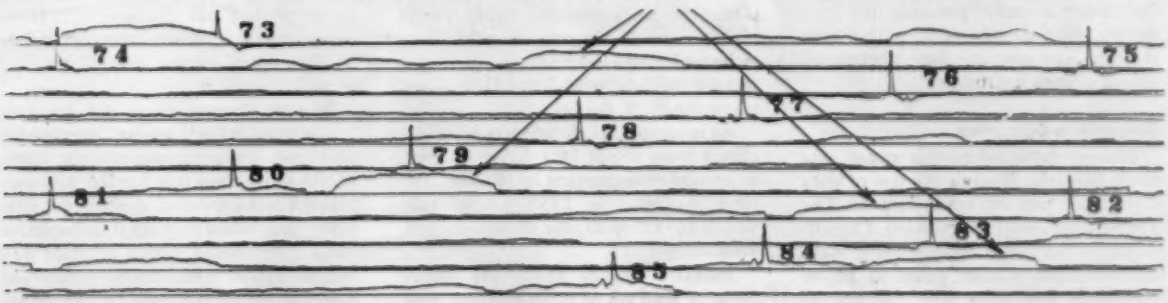


FIG. 11. **Rod wear in the tubing** is indicated by irregular chart line deflections. Most obvious is that shown in joints 74, 80, 81 and 84.

head water. The caliper charts represent the corrosion rate status and location throughout the entire length of tubing string. A metal coupon represents only that point where it was left exposed to the corrosive agents.

When the rate of corrosion is determined by the average weight loss of the coupon, if corrosive pitting is present, the value will not represent the effective rate of corrosion such as caliper surveys do. The steel coupon exposures are also of little value when the coupon becomes coated with paraffin during exposures.

In high pressure sweet oil well corrosion, the wells quite often make as little as 0.1 per cent water. Under such a condition, it is nearly impossible to obtain a sufficient amount of water to determine iron content. In low pressure sweet oil well or gas well corrosion, there is sufficient water to obtain the iron content, but the questions arise, "How much of the iron content is coming from the formation?", and "Is the iron content the result of corrosion over the entire length of tubing or at a localized spot?" To answer these questions, it becomes necessary to chart and measure the results of corrosion while the tubing is under pressure and producing oil or gas. To do so at this time requires the use of the mechanical tubing caliper instrument.

The Author

Jack T. Martin is a district petroleum engineer for The Texas Company in the Producing Department's Louisiana Division. A substantial part of his time during the past few years has been devoted to corrosion problems. He began his employment with The Texas Company after receiving a BS degree in mechanical engineering from the University of Colorado in 1948. While attending the University of Colorado, he served as an instructor in the engineering metallurgy laboratory.

Acknowledgments

The preparation of this paper was made possible through the use of data collected from the operations of The Texas Company's Producing Department, in the Louisiana Division. Acknowledgment is also given to fellow petroleum engineers who contributed helpful suggestions during the preparation of the paper. ★ ★ ★

Swensrud Predicts

Future Oil Demands And Supply Trends

INCREASING oil consumption, both within and outside the United States, and finding, developing, and getting to market the needed supplies were pictured as a long-term trend facing the petroleum industry, by S. A. Swensrud, chairman of the board of Gulf Oil Corporation.

Swensrud's talk, in which he described oil as "now the largest of all industries other than agriculture . . . and growing rapidly," was given before the spring meeting of the Eastern district, division of production, of the American Petroleum Institute.

He keynoted his broad discussion of future oil demand and supply trends with this forecast:

"It appears probable that we shall find continuing need for moderately increasing quantities of oil from other areas over the near-term future.

"Somewhere along the line, perhaps several decades hence, if and when U. S. productive capacity ceases to expand, or actually begins to decline, we shall then need much greater quantities from other sources to meet the domestic demand."

Because of this situation, more and more American companies have been venturing into oil activities in foreign areas. "American companies, fortunately, I believe are now the largest owners of oil reserves abroad as they are here at home," he commented.

Domestic oil use rises as ratio of reserves declines. Although estimated U. S. oil consumption of 14 million barrels per day by 1975 is high is comparison with the 1955 rate of 8,400,000 bbl per day, Swensrud pointed out that it represents an increase of less than 3 per cent a year which seems conservative as compared with much higher rates of the past. By 1975 it is estimated that oil consumption in the rest of the free world will have overtaken the U. S. figures.

As to supply, U. S. reserves have declined from about 16.1 times as great as annual consumption in 1920 to 10.7 times as great in 1955 — a year in which 56,000 wells, the all-time record, were drilled.

Industry studies as to the future ratio of reserves to consumption "usually show reserves and productive capacity rising for a number of years ahead and then somewhere along the line beginning to drop off as the ability to find new reserves fails to offset . . . the decline."

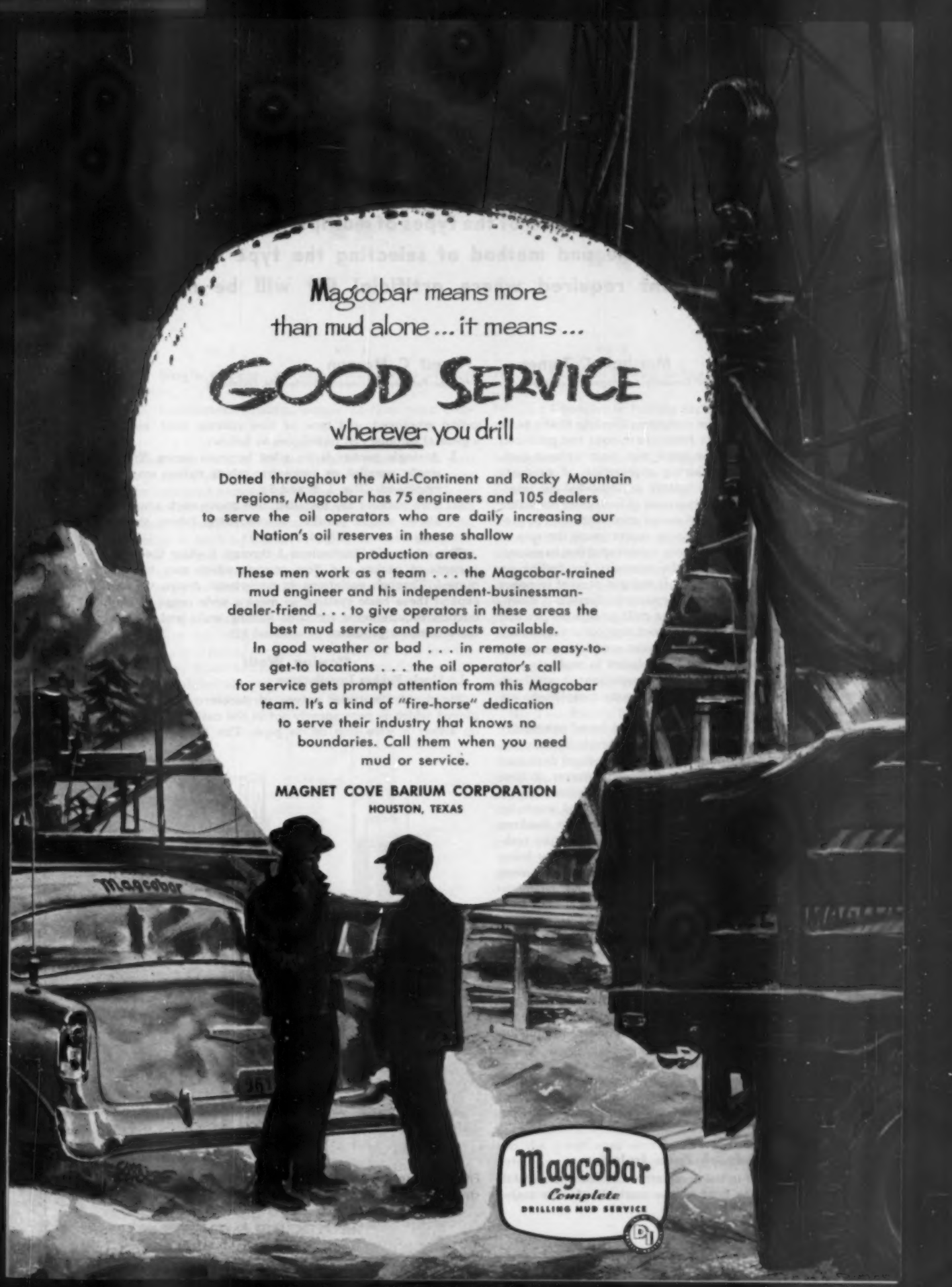
S. A. Swensrud

While noting no one could tell when the decline would come, he exhibited one speculative chart prepared by the Chase Manhattan Bank which, on the basis of future discoveries in the U. S. equalling past discoveries, indicates U. S. production beginning to fall off in the 1970's.

Oil industry wants enlarged but carefully planned highway program with reasonable taxes and competitive oil sales on new roads. Commenting on the projected federal highway program, Swensrud feels this will broaden motoring opportunities — and gasoline use.

The oil industry, he emphasized, strongly supports an improved highway system, but feels that: "We must try to protect our customers . . . from unreasonable gasoline taxation either by the states or the federal government."

Present federal taxes on gasoline (originally levied as an emergency tax) and on other automobile items would more than pay for the highway plan. Adding another cent to gasoline taxes and increasing other automotive taxes as proposed would produce $30 billion above road costs — thus the motorist would not only be paying for the total highway program but a good deal more besides.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MULTIPLE-ZONE COMPLETIONS

An authoritative discussion of the types of multiple-zone completions that are available and method of selecting the type completion and equipment required where artificial lift will be required

Marshall C. Turner
Monterey Oil Company, Los Angeles, California

Forrest C. Morgan
Phillips Petroleum Company, Bartlesville, Oklahoma

THE term "multiple-zone completion" refers to the technique whereby two or more zones are opened and produced simultaneously through the same well bore without commingling of fluids. Maintaining segregation of products from each zone may be voluntary as indicated by reservoir characteristics; for the purpose of increased allowable production; or compulsory in compliance with the requirement of regulatory bodies. During recent years the rate of such completions has been greatly accelerated due to mounting development costs, plus the necessity for finding an economic means of recovering oil and gas present in zones of small reserves. There is no reason to foresee a downward trend in this program, for as drilling gets deeper and more expensive, zones which cannot support a reasonable return for the drilling of a single zone completion may become economical if they can be included in multiple-zone completions. To date multiple completions have been mostly dual zone completions; triple zone completions are as yet rare.

The advantages of dual-zone wells are based principally upon those economic factors related to development costs. It is a relatively simple technique to produce dual-zone oil wells wherein both zones are flowing. However, in time formation pressures decline, natural flow ceases, and it becomes necessary to lift fluid from one or both zones by placing adequate lifting equipment within the confines of a single string of casing. The range of production techniques applicable to dual completions is continually being expanded by the development of new tools and equipment thereby providing an increasing range of production methods to dual zone wells. Dual-zone completions do not have indiscriminate application; they offer considerable economic attraction if producing and reservoir characteristices indicate that the desired production rates can be efficiently produced after cessation of natural flow. The degree of success in artifically lifting fluid from a dual completion will be, to a large extent, dependent upon the forethought and planning relative to the designing of the casing and completion program so as to fit the anticipated production requirements.

This article will not cover a discussion of the factors affecting the justification for dually completing a well. It will assume that the decision has been made and will deal with methods and equipment considerations in making multiple-zone well completions.

Methods of Zone Isolation

In a discussion of initial completion methods where both zones are brought in flowing, the methods of zone segregation employed, and type of flow courses used, enable a general summary of techniques as follows.

I. A single packer is installed between zones. Either single, parallel, or concentric tubing strings may be employed. (Fig. 1, 2, and 3)

II. Two packers are installed, one above each zone. As above, single, parallel, or concentric tubing strings may be used. (Fig. 4, 5, and 6)

The schematic illustrations 1 through 6 show the basic systems of packer and flow courses which may be employed. Through variations in equipment design we can expand these basic systems to meet a wide range of production requirements for both flowing wells and for the more complex problems of artificial lift.

Flowing Wells

I. Single Packer Installations

Figure 1A illustrates a type of packer commonly employed which is permanently set in the casing by running on either a wire line or on pipe. The tubing string is

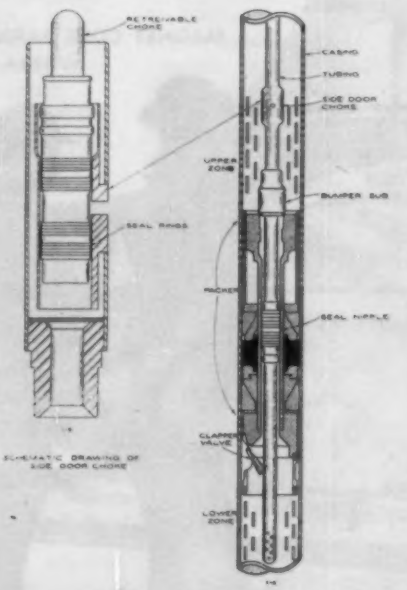

FIG. 1. **Conventional single packer,** single tubing string dual completion installation.

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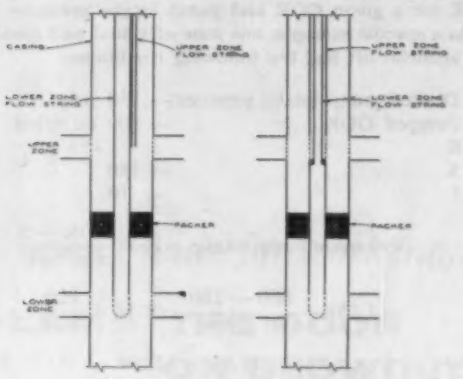

FIG. 2. FIG. 3.

FIG. 2. **Single packer, parallel tubing** type of dual completion.

FIG. 3. **Concentric tubing,** single packer type completion.

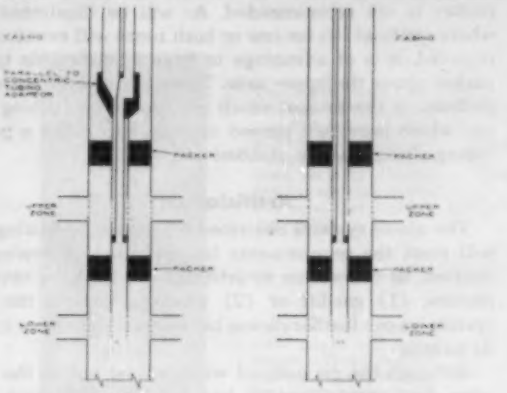

FIG. 5. FIG. 6.

FIG. 5. **Parallel tubing string,** dual packer installation.

FIG. 6. **Concentric tubing string** completion using two packers to separate zones.

equipped with sealing nipples which provide the seal between zones when inserted into the packer. The packer may be equipped with a bottom clapper valve which closes by pressure differential when the tubing is pulled; thus each zone may be swabbed-in separately by raising or lowering the tubing. A latching device is available for locking the tubing to the top of the packer should this be desirable where high differential pressures may exist. In this installation, the upper zone must flow through the annulus and the lower zone through the tubing.

Figure 1-B shows details of a side-door choke which can be placed in the tubing string for increased flexibility of operations. By running the proper choke on a wire line the side port may either be closed or opened; thus drilling fluid may be circulated out and both zones brought in together. The upper zone may be shut-in and the lower zones brought in separately. Each zone may be fractured or acidized separately — the lower zone through the tubing, and the upper zone through the casing.

Parallel tubing string installations (Fig. 2) are frequently used. These installations offer the possibility of longer flowing life for the upper zone by eliminating flow through the relatively larger area of the casing. Where the upper zone will deposit paraffin in the casing annulus, some operators use a parallel string of internally plastic coated tubing, extended to the depth where the paraffin first occurs. If one of the tubing strings is made up with integral upset (no collars) type of joints, or joints with beveled collars, the tubing may be run singly after the first string of tubing has been landed. Considerable success has been achieved with this practice, parallel strings as long as 12,500 ft having been run in and out one at a time.

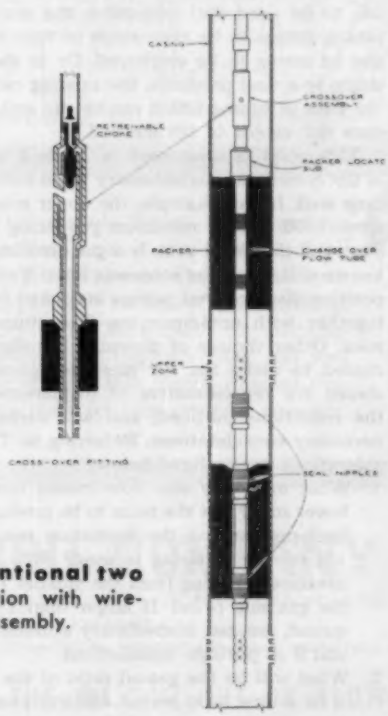

FIG. 4. **Conventional two packer** installation with wire-line crossover assembly.

II. Two Packer Installations

With the addition of special equipment, the two packer installations can be made to provide a high degree of flexibility. Figure 4 shows a selective cross-over flow nipple which is installed in the tubing string directly above the top packer. Special mandrels can be run into this assembly by wire line to selectively flow either zone through either the tubing or casing annulus. Concentric tubing extensions project below the top packer to keep the zones separated. The flow reversals can be made at any time without killing the well. In this illustration, the lower zone flows through the center tubing extension and is diverted into the casing at the cross-over nipple. The upper zone flows through the tubing extension annulus and into the tubing string. Either zone can be shut-in; either zone may be fractured or acidized through the tubing; and each zone can be swabbed-in separately through the tubing. If one zone stops flowing, pumping equipment can be installed in the tubing to pump fluid within the limitation imposed by lack of gas-oil separation.

The two packer installations using parallel or concentric tubing strings have the added advantage that mud may be left in the casing should formation pressures make this desirable (Fig. 5 and 6). Use of the two concentric strings with two packers has not received wide application because of lack of flexibility in handling the upper zone. It cannot be swabbed-in separately unless the smaller tubing is pulled and the lower zone shut-in, flow courses are usually restricted, and bottom-hole upper zone pressure tests are difficult to obtain.

General use of a permanent type packer as the upper

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packer is not recommended. As will be illustrated later, where artificial lift for one or both zones will eventually be required, it is of advantage to have a retrievable type of packer above the upper zone. There are several retrievable packers on the market which are run on one tubing string and which provide a second opening into which a parallel tubing string may be stabbed and latched.

Artificial Lift

The above systems described for dual-zone flowing wells will meet the requirements for operation of flowing production. In conversion to artificial lift, we have two main choices, (1) gas-lift or (2) pumping; and in the latter system we can further choose between rod pumps or hydraulic pumps.

Although the majority of wells will be put on the pump after flow ceases, gas-lift has definite application under certain reservoir conditions. The application of gas-lift to the systems described in Fig.. 1 through 6 is evident. Gas-lift valves may be installed on parallel tubing strings, or by running small diameter tubing, single point injection can be used. Fig. 7 illustrates a single point injection installation.

In some instances, we may be able to gas-lift or plunger-lift dual zones for several years, possibly until one zone reaches its economic limit and the well can be reverted to a single producer. In the majority of wells, these methods offer only intermediate techniques and eventually the wells will be pumped with either hydraulic or rod pumping systems. An essential requirement of an oil pump installation is the separation of gas from the oil prior to fluid entry into the pump. The two concepts of (1) gas-oil separation in the well bore and (2) bleeding of casing gas at the surface with resultant removal of back-pressure on the well, form the fundamental requirements of an oil well pumping system.

If the pump must operate from below a packer, then all of the produced gas and oil must pass through the pump. This lack of gas-oil separation can impose severe operating problems such as shock loads from gas pound in addition to a loss of oil production. Free gas in the pump bore reduces efficiency because part of the plunger stroke must be utilized to expand and compress this gas before valve action begins. If maximum theoretical pump volumetric efficiency is defined as the ratio of one barrel of stock tank oil, to the volume, in barrels, occupied at pump intake conditions by the barrel of oil and its associated gas, the following expression may be made:

$$\text{Max. PVE} = \frac{\text{1 bbl stock tank oil}}{\text{Volume downhole of 1 bbl stock tank oil and associated gas}}$$

or

$$= \frac{\text{1 bbl stock tank oil}}{B + \dfrac{GOR - S}{f \times 5.61}}$$

Where:

B = Formation Volume Factor
GOR = Pumped gas-oil ratio - cu ft/bbl
S = Solubility cu ft/bbl
f = Conversion factor cu ft gas at surface to cu ft at pump intake conditions

The above equation represents a simplified analysis of PVE since pump compression ratio, liquid compressibility, gas deviation from ideal behavior, pump clearance volume, and other factors influencing PVE are not considered. Field tests have proved these factors to have minor influence on PVE but generally cause slightly lower PVE's; thus, the above definition represents the maximum theoretical PVE for a given GOR and pump intake pressure.

As a specific example, one zone of a dual well considered for artificial lift had the following conditions:

Desired pump intake pressure	— 150 psig
Pumped GOR	— 800 cu ft/bbl
B	1.158
S	— 180
f	— 10

$$\text{Volume at pump intake} = B + \frac{GOR - S}{f \times 5.61}$$

$$= 1.158 + \frac{800 - 180}{10 \times 5.61} = 1.15 + \frac{620}{56.1}$$

$$= 1.158 + 11.05 = 12.208$$

$$\text{Therefore Max. Theo. PVE} = \frac{1}{12.208} = 8.3 \text{ per cent}$$

Assuming a bottom-hole pump displacement of 200 bbl per day, this means production would be limited to 17 bbl per day. Should the well be capable of producing more than 17 bbl per day at 150 psig bottom-hole pressure, the equipment could not keep the well pumped down and production would be restricted. In this example, facilities were provided to vent free gas and the desired production of 100 bbls per day was obtained.

For a single zone well, under the ideal situation, reservoir characteristics should be the main determinant in establishing the production technique. Given the production and decline rates, gravity, gas-oil ratio, formation pressure, and P.I. data, we can establish whether the well should be gas-lifted, intermitted, operated with a plunger lift, or a hydraulic or rod pump installed. However, the situation is seldom ideal and our choice of equipment is affected by such factors as proration schedules, existing lease facilities, cost of equipment, and competitive conditions. When, in addition, we introduce considerations relative to dual-zone completions, we find additional factors that will affect our choice of production equipment. The fluid lifting methods to be used will determine the number and sizes of tubing strings to be run, which in turn will determine the size of casing to be employed. Or in the conversion of a single to a dual producer, the existing casing size will limit the sizes of tubing which can be run and, here again, influence our choice of lift method.

This point is illustrated in Table I which shows some of the considerations necessary when contemplating a dual-zone well. In this example, the upper zone is to be pumped from 7300 ft with minimum producing bottom-hole pressure, and the lower zone is a gas distillate zone which it is known will flow to its economic limit. Various methods with positive displacement pumps are listed for the upper zone, together with accompanying flow courses for the lower zone. Other choices of pumping installations could be included to make the list more complete; however, those shown are representative of displacements available for the conditions outlined, and will serve to illustrate the necessary considerations. Referring to Table I, these considerations are outlined below:

1. What minimum size flow course can be used for the lower zone? For the rates to be produced, will excessive back-pressure on the formation result if a 1, 1¼, or 1½-in. tubing string is used? Will the lower surface pressure resulting from the smaller tubing string affect the gas sale price? If larger than 1½-in. tubing is required, we can immediately eliminate Nos. 1, 4, 7, 8, and 9 as possible installations.
2. What will be the gas-oil ratio of the upper zone? Will it be so low as to permit efficient pump operation with-

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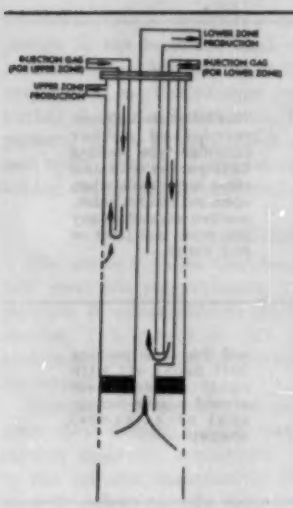

FIG. 7.

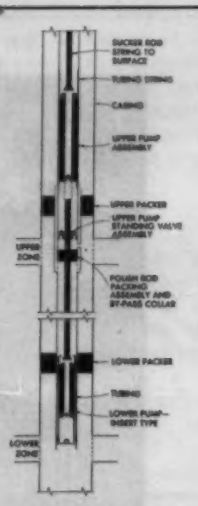

FIG. 8.

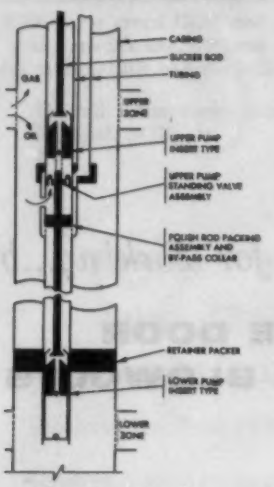

FIG. 9.

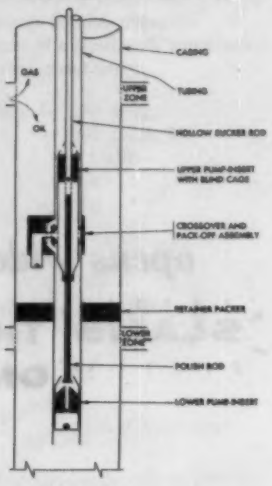

FIG. 10.

FIG. 7. **Gas lift technique** for single point injection or jetting gas.
FIG. 8. **Two zone pump** used with dual packer installation.
FIG. 9. **Two zone pump, single packer** system using parallel tubing strings.
FIG. 10. **Hollow sucker rods** used to produce upper zone in two zone pump installation.

out gas withdrawal from below the pump? If bottom-hole gas separation is necessary, Nos. 2, 3, and 5 are eliminated. If it is believed that the upper zone can be successfully pumped from below a packer, a greater range of pump displacement is available; however, in considering pump operation without gas separation, production rates should be based on calculated pump efficiencies as determined in the previous example.

3. What peak rod stress will be required? Carbon manganese rods can give satisfactory performance at stresses up to 26,000 psi and it now appears possible to use high tensile rods with operating stresses up to 40,000 psi.
4. What is the maximum fluid rate to be produced from the upper zone? The rate obtainable will have to be estimated in the light of the above factors.

With answers to these questions, the type of equipment indicated and the casing size required become evident. For example, if it is assumed that 200 bbls per day are required from the upper zone with gas-oil separation below the pump, and at least a 1¼-in. flow string is needed for the lower zone, we are forced to use 7-in. casing and are limited to a long stroke hydraulic pumping unit or a bottom-hole hydraulic pump. The question then becomes one of predicted operating costs and performance.

In general, the operator who has completed a number of dual zone wells with 5½-in. casing faces some limitations when artificial lift is required for both zones. Seven-inch pipe offers the minimum internal diameter which permits installation of two 2-in. tubing strings, and this advantage greatly increases the possible combinations of production equipment which may be utilized. Economic justification for 7-in. casing seems apparent for dual oil zone completions unless it is known that one zone will flow to depletion through small tubing without substantial sacrifice of production. In general, the additional cost for completing a well with 7-in. pipe instead of 5½-in. will vary from approximately $5000 for a 6000 ft well to $16,000 for a 10,000 ft completion. Dual-zone wells completed with 7⅝ or 8⅝-in. casing offer more room with which to work but the limitations are essentially the same as in 7-in pipe. If by reason of drilling a dual completion, larger than 7-in.,

TABLE 1. Sub-surface production equipment for proposed dual completions.
Conditions: Upper zone; depth 7300 ft; fluid to be produced with bottom-hole pump.
Lower zone; depth 7500 ft; gas distillate zone will flow to economic limit.

No.	Proposed Lower Zone Flow Courses	Proposed Upper Zone Tubing	Pumping Method	Upper Zone Gas-Oil Separation in Casing Possible	Top Rod Size	Estimated Pk. Rod Stress PSI	Pump Size	Pump SPM	Estimated* Maximum Production Bbls./Day
For 5-½" (17.) Casing									
1	1" EU	2" EU	74" stroke beam	Yes	⅞"	28,000	1-¼"	10	60
2	Casing	2-½" EU	120" stroke beam	No	1"	28,000	1-¼"	10	56
3	Casing	2-½" EU	300" stroke hydraulic	No	1"	32,600	1-¾"	5-½	154
4	1¼" Hyd. CS	2" Hyd. CS x ¾" EU	Conventional hydraulic pump 60" stroke	Yes	—	—	2"x1½"	10	115 (250 psi loss in ¾" tbg.)
5	Casing	2-½" EU x 1¼" EU	Conventional hydraulic pump 24" stroke	No	—	—	2½"x1¼"	71	105
For 7" (23.) Casing									
6	2" EU	2" EU	74" stroke beam	Yes	⅞"	28,000	1-¼"	10	60
7	1½" EU	2½" EU	300" stroke hydraulic	Yes	1"	32,600	1-¾"	5-½	360
8	1½" EU	2½" EU x 1¼" EU	Conventional hydraulic pump 60" stroke	Yes	—	—	2½"x1-¾"	18	270
9	1" EU	3" EU x 1¼" EU	Conventional hydraulic pump 24" stroke	Yes	—	—	3"x1½"	64	425

All installations feasible in 5½" casing can be run in 7" casing with increased annular clearance.
*Assumed 70% PVE with Gas-Oil Separation and 30% PVE without Gas-Oil Separation.

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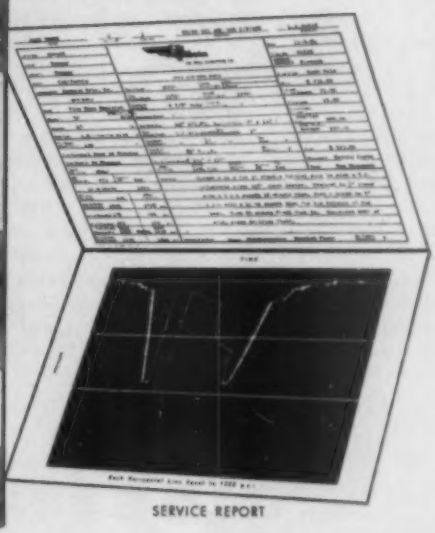
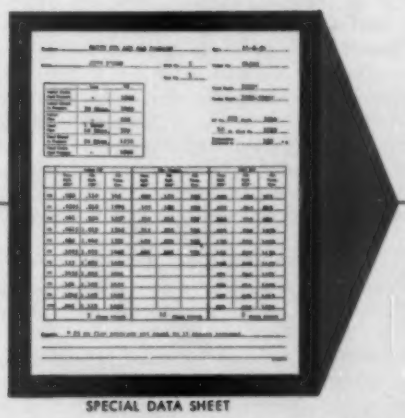


SERVICE REPORT



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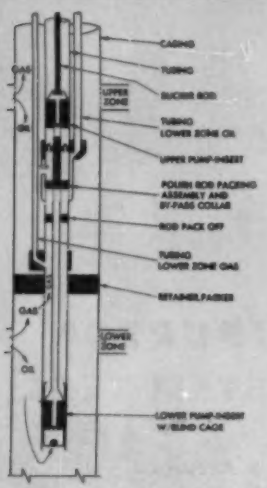

FIG. 11.

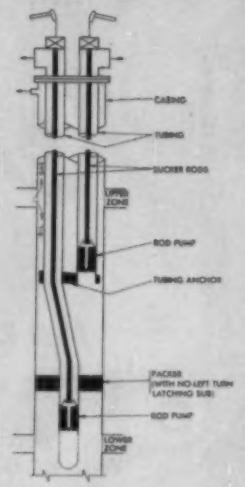

FIG. 12.

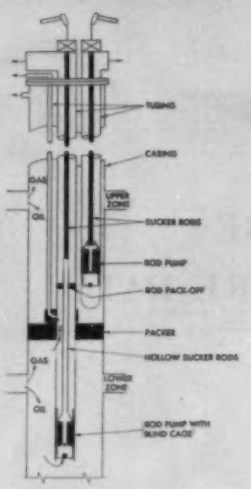

FIG. 13.

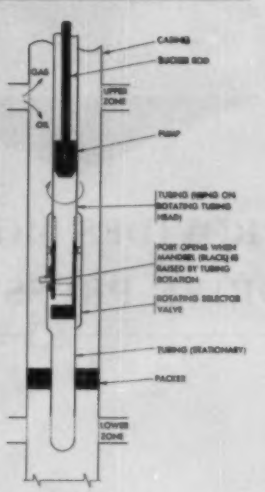

FIG. 14.

FIG. 11. **Bleeding gas** from both zones in pump application.
FIG. 12. **Pump applications** in single packer parallel tubing type completion.
FIG. 13. **Three string installation** used to bleed gas during pumping of both zones.
FIG. 14. **Selective dual installation** used to intermittently produce zones.

pipe is required in comparison to drilling twin wells with 5½ or 7-in. casing, the economic advantages of dual completions diminish.

At this point we might review some of the basic dual zone pumping designs which have been utilized in present field installations or contemplated for future installations. Figures 8 through 17 are presented to illustrate the various equipment and designs that have become available. It would be too lengthy to attempt a review of all of the various combinations of lift equipment which can be installed in duals. The reader can take these basic designs and can recombine or modify the equipment to fit his particular need and casing size. Both producing and equipment companies have devoted great efforts toward developing equipment which provides down-hole gas-oil separation in dual zone pumping installations. The result has been a number of new items which can be adapted to duals in a multiplicity of combinations with standard pumping systems.

Two Zone Pump Designs

Fig. 8 illustrates the working principles of a dual-zone pump. Essentially the equipment consists of two rod pumps operated in tandem, each pumping from below a packer. The lower zone flow course is through the casing annulus above the top packer and the upper zone is pumped through the tubing. The main components are the upper and lower pump assemblies connected together by a polish rod traveling through a packing assembly. The two pumps may be any distance apart in a well. The upper pump is an intricately designed assembly in which a polish rod is fastened to the bottom of the plunger, and the standing valve, or valves, is placed in the annular area around this rod. The lower pump may be a conventional pump. Since the operating speed is the same for both pumps, displacement differences are obtained by variations in bore sizes. The chief disadvantage of this installation is lack of gas-oil separation; all gas produced from each zone must pass through the pumps. Also, it is not possible to conduct fluid level tests or inject corrosion inhibitors.

Fig. 9 shows a two zone pumping design with the upper packer eliminated. The lower zone fluid by-passes the packoff and upper standing valve assemblies and is produced through a small diameter parallel tubing string rather than the casing annulus. The upper zone is pumped through the upper pump and fluid flow is through the conventional or large tubing. The fluid courses can be reversed, if desired, by use of an additional packoff above the upper pump. This will permit inhibition of lower zone fluid in the large tubing by use of hollow sucker rods.

This design permits gas-oil separation in the casing annulus and good pump submergence for the upper zone. Also, it is possible to run fluid level measurements and inhibit the upper zone.

Fig. 10 is a design utilizing one casing packer, a dual zone pump, and hollow sucker rods. The lower zone fluid is pumped up the tubing, by-passes around the packoff assembly and flows up the tubing-hollow sucker-rod annulus. The upper zone fluid is produced through the upper pump and up the hollow sucker rods by the use of a blind cage on the upper pump.

The design has considerable merit in 5½-in. cased wells within the depth limitation of hollow sucker rods. Gas-oil separation is achieved in the upper zone; and fluid level surveys and inhibition are permitted for the upper zone. The use of 2½-in. tubing and 5½-in. cased wells offers more flexibility in selection of pump bore sizes, and an easy method of anchoring tubing is afforded which is not easily achieved with clamped parallel strings.

Fig. 11 shows a design involving three tubing strings, a two zone pump, and one casing packer. It may be noted that gas-oil separation and pump submergence are provided for both zones. Lower zone oil is pumped up the hollow sucker rods, past the packoff and standing valve assembly, and up the small diameter tubing string. Lower zone gas flows up the other small diameter tubing string. Upper zone oil and gas are produced as in previous design.

Two Pumping Unit Designs

Fig. 12 shows a design providing gas-oil separation in the upper zone. Two pumping units are used in conjunction with two 2-in. tubing strings. The tubing strings are run independently and the second string is latched into the dual string anchor. The second tubing string is 2-in. EU tubing with couplings turned down to 2.91-in. OD. This design has one noteworthy advantage over the dual zone

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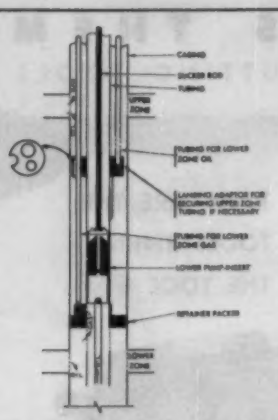

FIG. 15. **Multiple tubing type unit** used to pump lower zone only.

pump design in that individual speed control is possible for each zone. It has the disadvantage of higher initial cost.

Fig. 13 shows a design providing for gas-oil separation in both zones by addition of a third tubing string. The small diameter tubing string is clamped with Acme metal bands to the long string of 2-in. EU tubing which is run first. The second string of 2-in. EU tubing has couplings turned down to 2.91-in. OD.

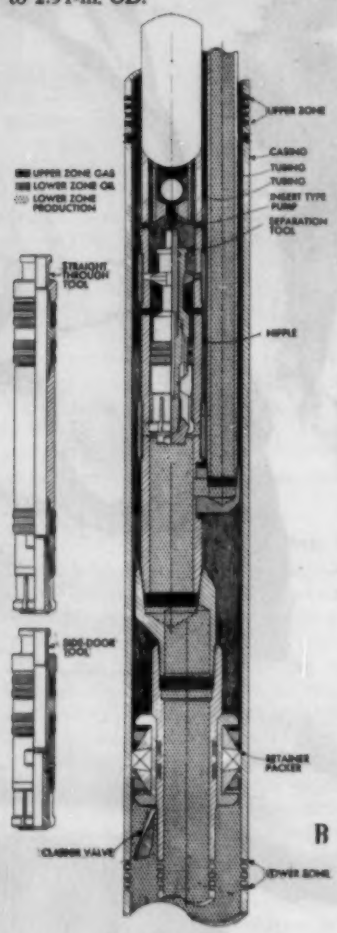

FIG. 16.

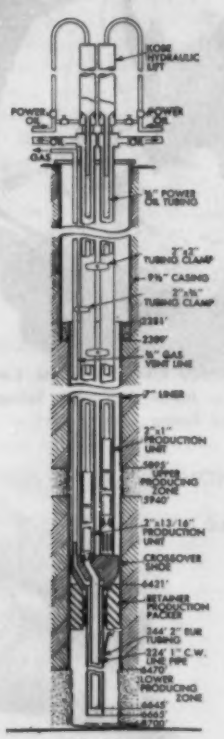

FIG. 17

FIG. 16. **Multiple tubing installation** used in pumping upper zone and flowing lower zone.

FIG. 17. **Hydraulic pumping installation** used in Honolulu Oil Company's Covington A-1 and AC-1 dual zone completion.

This installation has lower zone pump submergence and gas-oil separation, accomplished by use of a blind cage on the lower pump and by pumping through hollow sucker rods to a packoff in the tubing placed just above the casing packer.

Intermittent Dual Zone Pumping

Fig. 14 shows an intermittent method of artificially producing dual zone wells with gas-oil separation for the upper zone. This design utilizes a rotating selector valve. Basically it is a side-door choke operated by tubing rotation at the surface. With the mandrel in the upward position, the lower zone is closed off and the upper zone is pumped as in a single zone well. With the mandrel in the lower position, the upper zone is shut-in and the lower zone is open to the pump. All produced gas from the lower zone must pass through the pump. A special rotating tubing head is required to permit easy surface zone selection as desired by the pumper.

In areas operating under production allowables, this method is adaptable only to those wells having sufficient productivity in each zone to produce the allowable in 15 days or less.

Lower Zone Pumping — Upper Zone Flowing

In Fig. 15 a single packer is installed above the lower zone. Gas separation for the lower zone pump is achieved through a small bore tubing string tied to a dual string adaptor directly below the pump. The upper zone flows through the casing annulus or through a third tubing string as shown. The upper zone may be gas-lifted if desired by means of this third string. A feature of this installation is the use of the tubing adaptor which is run on the main tubing and which allows passage for a second string and a receptacle locking assembly for a third string. In practice, all three strings are clamped together, or, the lower zone strings are run together and the upper zone tubing run separately, either suspended or landed in the adaptor.

Lower Zone Flowing — Upper Zone Pumping

This installation shown in Fig. 16 uses a single retainer packer above the lower zone. Lower zone flow is diverted from the main tubing into a smaller parallel string by means of a separation tool. This smaller string may be run simultaneously with the larger string, or as is becoming more common, it is run separately after the first string has been landed. To enable this, of course, one of the strings must have integral type jointing, or the collars must be carefully beveled. The upper zone has gas-oil separation in the casing. Pump intake is preferably below the casing perforations. An insert pump is used, whether rod or conventional hydraulic. A choke nipple assembly is installed below the pump at the oil intake into the tubing, and chokes are available which will pass through the pump hold-down. Thus, by using the proper tool (separation, side-door, or straight through), the lower zone can be swabbed, fractured, treated, pressure tested, etc., through the large tubing with the upper zone isolated.

Hydraulic Pump Designs

Hydraulic pumping has also been used in dually completed wells. One of the more elaborate designs which has been installed is shown in Fig. 17. Gas-oil separation is provided for both zones in this design. The two zone pumping equipment consists of two conventional type hydraulic production units. The ¾-in. macaroni or power oil strings are run concentrically in standard 2-in. production tubing strings. A ¾-in. tubing string is used to vent the gas from the lower zone.

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Helicopter transportation in offshore drilling is increasing rapidly as exploration extends further from land. Shown above is a Sikorsky S-55 carrying a drilling crew out to a mobile drilling platform.

P 368.311

THE HELICOPTER

New Tool of the Petroleum Industry?

Introduction of the "whirlybird" to exploration and development have opened up new vistas for the oil man. Here's a closer look at the 'copter.

George E. Tarbox
Stanolind Oil and Gas Company
Oklahoma City, Okla.

WHETHER it be exploration in the Louisiana swamps, the rugged Colorado Plateau, in foreign countries without roads or drilling operations on the continental shelf, the oil industry owes much to the helicopter for fast transportation. It has been used to move men and materials to and from almost inaccessible areas. Many oil operators are using contract helicopters (or their own) for special jobs, including The Texas Company, Shell, Richfield, Socony, General Petroleum, Humble and others. Two smaller companies utilizing this aircraft have been Signal Oil Company and Tex-Harvey Oil Company. A number of geophysical contractors also employ helicopters.

Four large firms (Bell, Hiller, Sikorsky and Piasecki) are making helicopters on full production-line basis, with other aircraft companies (Cessna, McDonnell, and Kaman) close behind. Although the greatest number of "whirlybirds" produced still go to meet military demands, availability to commercial flying and exploration companies has been increasing steadily. With very few exceptions, helicopters used in exploration today by U. S. and Canadian firms are limited to the Bell models 47D, E, and G, and Hiller models 12A and B, and the larger Sikorsky S-55.

Gravity surveys. Recently a major oil company put a Bell helicopter to work with a gravity crew in the Louisiana marshlands south of New Orleans. It boosted production on the survey to four times what could have been accomplished using conventional marsh buggies. Fourteen-foot portable survey towers carried on the side of the aircraft were erected in the swamp and triangulation accomplished as the helicopter took readings at stations throughout the swamp. Indepeadent contractors estimate cost of such a survey at about $15.00 per gravity station, plus a fixed monthly charge to cover pilot and mechanic salaries, insurance, etc.

Seismic surveys. Seismic survey operations have utilized the helicopter in many ways. Humble Oil & Refining Company's seismograph crews have made use of 'copters for transportation in marshy country, eliminating time spent in getting the slow marsh buggies to location. The helicopter can also fly data to office computers and interpreters, often saving time and expense in cases where an area can, if necessary, be "reshot" before the crew leaves the vicinity. Humble's Seis Party 10 was able to increase by one-third to one-half the average number of tests shot each day. Use as a fast air ambulance to any location is a valuable safety feature to any survey of this type where other means of transportation may be excessively slow.

A Netherlands New Guinea exploration company, Nederlandsche Nieuw Guinee Petroleum Maatschappij, partially supported by the Standard-Vacuum Oil Company, contracted for a helicopter to assist in its jungle seismic operations because of the extreme difficulty of transportation. An example of time and labor saved in a single

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RETAINER PRODUCTION PACKER

PRODUCT NO. 415-D

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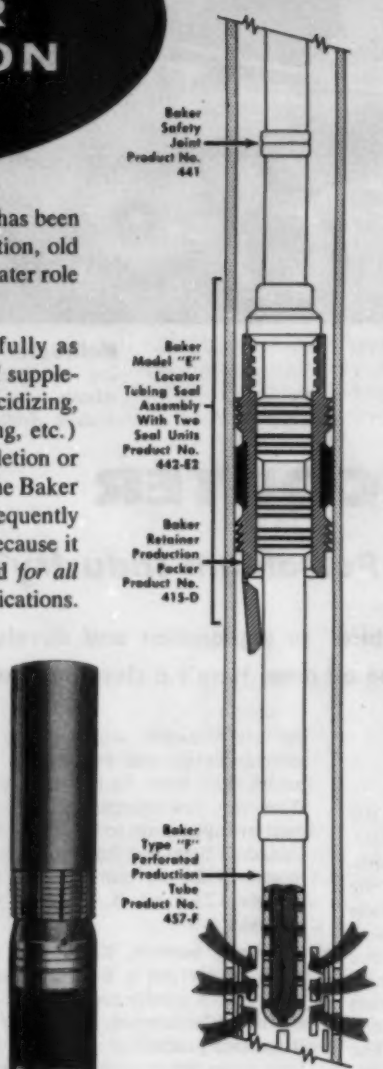
FEATURES

Can be run and set with the speed and accuracy of wire line, as well as on tubing or drill pipe.

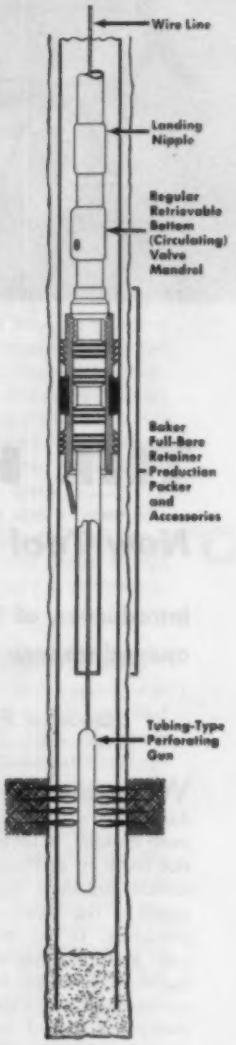
Holds any pressure from either above or below that is safe for the casing, even under temperatures in excess of 300°F.

Pack-off is independent of set-down weight or tension. Tubing string is free; just pick up (or unlatch and pick up) to remove it.

When tubing is removed, flapper valve closes to isolate zone below packer.


Baker Safety Joint Product No. 441
Baker Model "E" Locator Tubing Seal Assembly With Two Seal Units Product No. 442-82
Baker Retainer Production Packer Product No. 415-D
Baker Type "F" Perforated Production Tube Product No. 457-F

Illustrates Packer set in casing with Locator Tubing Seal Assembly and Production Tube installed for single zone production.


Wire Line
Landing Nipple
Regular Retrievable Bottom (Circulating) Valve Mandrel
Baker Full-Bore Retainer Production Packer and Accessories
Tubing-Type Perforating Gun

Illustrates typical Permanent-Type Well Completion Hook-Up showing perforating operation through and below the Packer.

Baker Locator Tubing Seal Assembly Product No. 442-82

Baker Retainer Production Packer Product No. 415-D

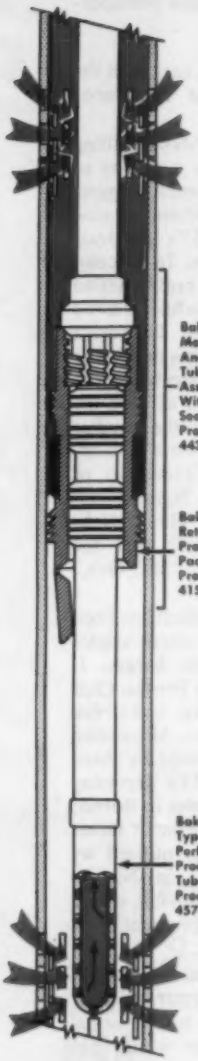
Successfully holds high pressures from above or below

... at shallow or record depths *even under temperatures in excess of 300°F.*

for all

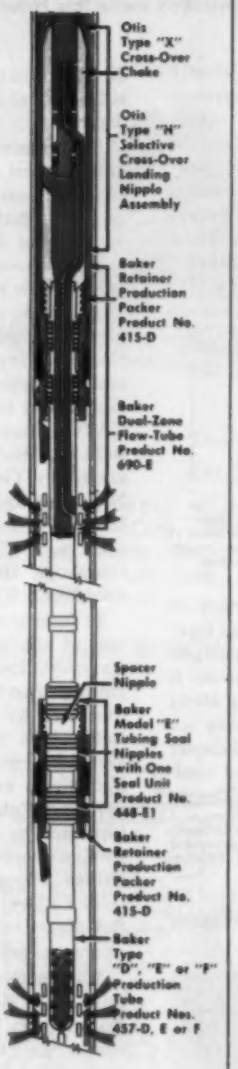
DUAL ZONE

SINGLE PACKER


Baker Model "E" Anchor Tubing Seal Assembly With Two Seal Units Product No. 443-E2
Baker Retainer Production Packer Product No. 415-D
Baker Type "F" Perforated Production Tube Product No. 457-F

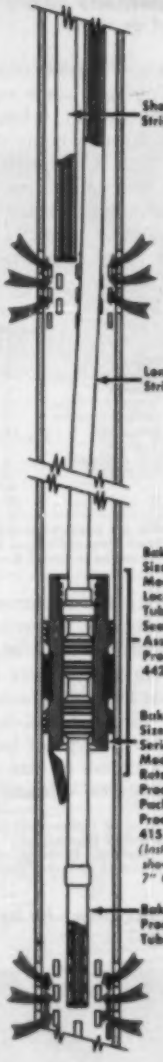
Illustrates Packer set in casing, with anchored production string for dual zone production. Tubing can be released from packer by rotating to right.

SELECTIVE CROSS-OVER


Otis Type "X" Cross-Over Choke
Otis Type "N" Selective Cross-Over Landing Nipple Assembly
Baker Retainer Production Packer Product No. 415-D
Baker Dual-Zone Flow-Tube Product No. 690-E
Spacer Nipple
Baker Model "E" Tubing Seal Nipples with One Seal Unit Product No. 448-E1
Baker Retainer Production Packer Product No. 415-D
Baker Type "D", "E" or "F" Production Tube Product Nos. 457-D, E or F

Illustrates selective two packer dual zone production hook-up (Baker-Otis) with Cross-over Choke installed. Flow pattern can be switched with Parallel Flow Choke.

PARALLEL STRING


Short String
Long String
Baker Size 100 Model "E" Locator Tubing Seal Assembly Product No. 442-E2
Baker Size 100 Series Model "D" Retainer Production Packer Product No. 415-D (Installation shown for 7" Casing)
Baker Production Tube

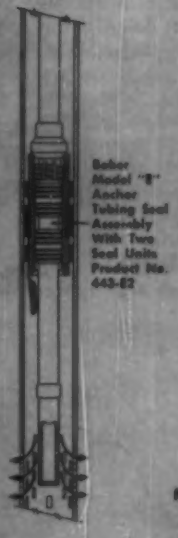
Illustrates simplest type of parallel string installation. Other installations involving two packers with full-opening tubing running through and below lower packer available.

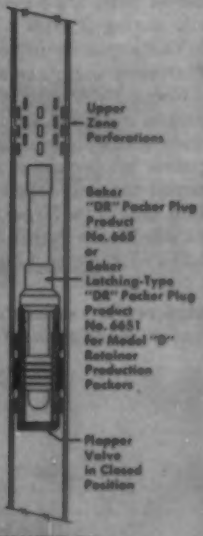
SUPPLEMENTAL APPLICATIONS

WATER OR GAS INJECTION

The Baker Retainer Production Packer contains features that permit it to be used as a squeeze or testing tool as well as a temporary or permanent bridge plug. It is thus used in a variety of supplemental applications such as gas or water injection, testing, fracturing, acidizing, etc., that may be required either during the completion phase of a well or during a later phase.

FRACTURE, ACIDIZE SWAB-TEST OR SQUEEZE CEMENTING

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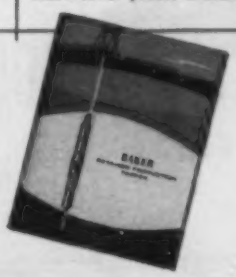

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day in which a Bell model 47C hauled 99 cases of dynamite to shot points, a feat which would have taken 100 natives three days to equal.

Shell Oil Company, through contract with General Geophysical Company of Houston, has experimented successfully with seismic work employing helicopters in northern Alberta, Canada, during the summer months when the soft, spongy "muskeg" makes ground travel all but impossible.

By using light recording equipment and specially-built drilling tools, the two Sikorsky S-55's were able to transport seismic equipment quickly and efficiently between cleared areas along the line of exploration. This operation, undertaken as an experiment last year, promises to allow year-round seismic exploration in areas formerly used only when the ground was frozen.

Another user of helicopters in seismic work is Geophysical Service, Incorporated, whose Seismograph Party 512 recently used a Bell model 47G for laying cables in otherwise impossible terrain in Colombia, South America. And commuting by 'copter made it possible for personnel to live in the nearby village of Ayapel instead of tents and houseboats.

Offshore drilling. Humble Oil Company now employs large S-55's in its offshore drilling program, cutting hours-long boat trips to minutes; this is particularly important when personnel or parts are needed at the drilling site during periods when water travel is dangerous or impossible. Magnolia Petroleum uses its smaller Bell 47G for 24-hour a day service in similar roles, and as offshore drilling platforms are used further from shore, more companies are certain to turn to the helicopter for fast, dependable transportation. One of the larger contracting firms in this field is Petroleum Bell Helicopters of Lafayette, Louisiana.

Duarable pontoons quickly installed make this Hiller 12B versatile transportation on land or water.

Helicopters now service almost fifty offshore drilling rigs; some operators own their own aircraft, while others lease 'copters through many different types of contracts. Unit service, half-time use of helicopters and special charters are common. A general breakdown of the Sikorsky and Bell craft (the most common types) is shown below*: (Gulf Coast Only)

Owner	Operator	Sikorsky S-55	Bell 47G
California Co.	California Co.	2	0
General Air Trans.	General Air Trans.	0	1
Glasscock	Glasscock	0	1
Helix Air Trans.	General Air Trans.	0	1
Hawk Helicopters	Hawk Helicopters	0	1
Humble	Rotor-Aids	5	0
Magnolia	Magnolia	0	1
Petr. Helicopters	Petr. Helicopters	4	5
Rotor-Aids	Rotor-Aids	0	2
Total		11	13

Note: The figures are approximate as most of the contractors listed own additional equipment which is used offshore as demand dictates.

In considering the construction of offshore heliports, size, access and load-carrying capacity are most important. Size varies from 14 ft square to 80 ft square with the average running about 50 ft square.* Size and load-factor are also affected by the type of helicopter used; a rule of thumb on size of landing area, whether on offshore rigs or on land, is to use a square area with the sides equal to at least 1½ rotor diameters.

In connection with offshore drilling units, almost every major company so engaged uses the helicopter. Biggest user of whirlybirds is Humble, now owning five Sikorsky S-55's and leasing five more Bell 47G's. In December of last year, these craft carried about 6000 passengers while serving nine offshore rigs.* The California Company owns and operates two S-55's and is planning to purchase two more Gulf leases its two S-55's, as does the CATC group.* Utilizing the smaller Bells are Sinclair (using two 47G's operated by General Air Transport of New Orleans), Western Natural Gas Company (one 47G by Hawk Helicopters of Corpus Christi), and the Glasscock Drilling Unit, "Mr. Gus," used by Shell.

In foreign operations, Shell has been one of the pioneers in using 'copter transportation to offshore barges. It employs two S-55's in the Persian Gulf (operated by Air Whaling, Ltd.), five Bell 47G's in the Lake Maracaibo area of Venezuela (operated by Aero Technica), and two S-55's servicing permanent platform rotaries in Borneo (operated by Armstrong Flint).* Other foreign 'copter service is utilized by British Petroleum, Ltd., in Nigeria (Hiller 12A's) and by Assam Oil, whose Bell aircraft aid in its geophysical operations in India.

Radioactive and magnetic exploration. Aero Service Corporation of Philadelphia, one of the largest aerial survey companies in the world, has now added helicopters to its air fleet for magnetometer and scintillation counter surveys. Another such operation in Canada is carried on by Hans Lundberg Explorations, Ltd. of Toronto, Ontario. And in jungle country, such as surrounds the large iron deposits in the Venezuelan plateau region, helicopters serve well as general reconnaisance vehicles for mineral exploration.

*Howe, R. J.: "Use of Helicopters in Offshore Drilling and Production Operations," presented before Southern District, Division of Production, API, San Antonio, March, 1956.

Liaison in swamp country with barge rigs or in exploration, the helicopter speeds operations. A Bell 47D approaches a remote rig.

*Howe, R. J.: "Use of Helicopters in Offshore Drilling and Production Operations," presented before Southern District, Division of Production, API, San Antonio, March, 1956.

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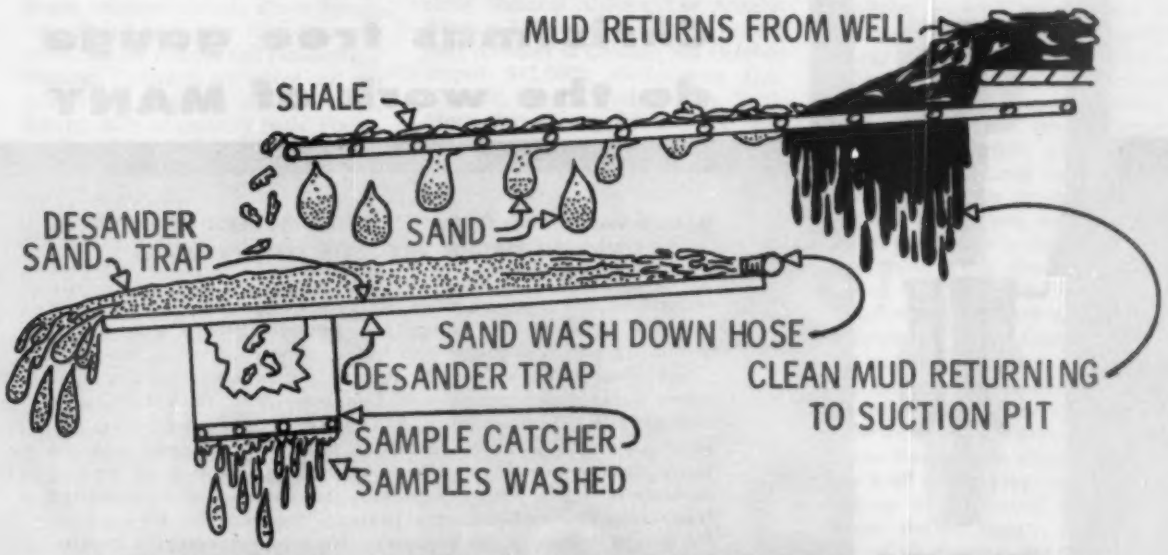
THIS IS HOW SAND IS SEPARATED FROM MUD



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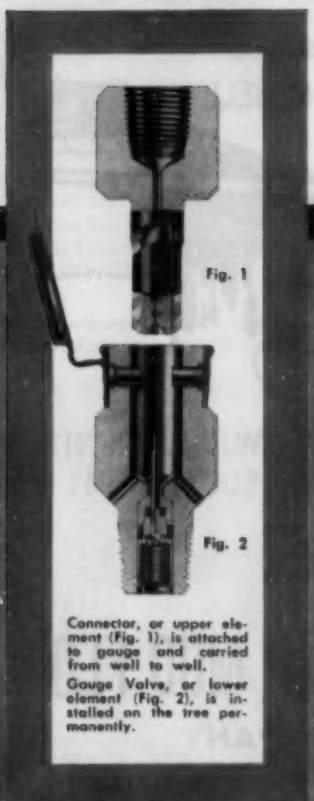

Connector, or upper element (Fig. 1), is attached to gauge and carried from well to well.

Gauge Valve, or lower element (Fig. 2), is installed on the tree permanently.

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Some topography, such as the uranium-rich Colorado Plateau, makes rough going even for jeeps and horses, and in these areas the helicopter can be indispensable. 'Copter surveys of this type are an improvement over fixed-wing "rim flying" in that landings can be made almost anywhere for samples and close evaluation. Even diamond drilling can now be done by carrying a lightweight drill on the side cargo boards of the helicopter.

Santa Fe Railroad's Haystack Mountain Development Company is one of the firms to use the "eggbeater" extensively to carry out air surveys of its uranium claims in the Grants, New Mexico, area. Helicopter companies engaged in this work are now in Grants and Albuquerque, New Mexico, Phoenix and Tucson, Arizona, and in Colorado. And in Texas, Southern Minerals Corporation of Corpus Christi is using 'copters for an aerial radiometric survey of 160,000 acres in fourteen South Texas counties (in some cases held by the Sun and Seaboard Oil Companies).

When comparing costs of such surveys to those done by fixed wing aircraft, it should be mentioned that, due to its greater maneuverability, only about 10 per cent of flight time is wasted by the helicopter in grid or pattern flying, while the figure rises to between 30 and 50 per cent using conventional aircraft.

Dual or triple crystal mountings are generally employed in scintillation work, along with a radio altimeter (to insure constant altitude above irregular terrain) and strip recorders synchronized for altitude and radioactivity readings. Contracts are varied and can usually be obtained on an acreage, hourly, daily or monthly basis. For an average thirty-day contract, expenses might run $200.00 per day plus $15.00 per flying hour.

Other uses. Owning a fleet of 8 Sikorsky and 22 Bell helicopters, Okanagan Helicopters, Ltd., of Vancouver has been instrumental in the development of Aluminum, Ltd., of Canada's huge hydro-electric plant in the rugged Kitimat region north of Vancouver. The Palisade Lake Dam construction and the supplying of many mountain-bound mining operations are commonplace to Okanagan, which has flown cement mixers weighing almost a ton with a single helicopter.

Crop-dusting is being done more and more by helicopters because of their ability to fly into tight "corners" at low speeds, and because of the fact that approximately 2,000,000 cu ft of air per minute passes downward through the main rotor system. Due to this downwash of air, insecticide boils up underneath the plant leaves as well as covering the tops, thereby insuring 100 per cent coverage, a feature which cannot be guaranteed by conventional dusters. Seeding after strip mining operations can be done in the same manner.

Scintillometer surveys of vast areas can be accomplished by mounting the sensitive unit on the forward cross-brace of this Bell 47G 'copter. Recording unit is shown mounted inside cockpit. (Photo courtesy Hawk Helicopters, Corpus Christi, Texas.)

Many helicopter "feeder" lines have sprung up in recent years, carrying passengers on short hops to airports and other points. Foremost in this field is New York Airways, which whisks the traveler from New Jersey Terminal to LaGuardia in 17 minutes for $9.50 (compared to 1½-2 hours at $12.00 and up for taxis); NYA is now second only to American Airlines in number of daily moveouts from LaGuardia Field. Other companies with mail, cargo, passenger and charter routes include National Airlines, Los Angeles Airways, Helicopter Air Service (whose mail revenues in Chicago last October topped $42,000), Helicopters Inc. (Denver), and Cleveland Air Taxi. More than fifty applications for helicopter service are now on the Civil Aeronautics Board docket.

Power and pipe line patrol is another specialty; lines between Los Angeles and Hoover Dam are patrolled in this manner at the rate of 500 miles a day. Aerial surveys and photographs, oil well fire fighting, traffic control (by the New York and Los Angeles Police Departments), and air ambulance evacuation are but a few of many utilizations; the Waggoner Estate Ranch in Texas has used its 'copter since 1952 for finding lost cattle and patrolling its 2700 miles of barbed wire fence. And more than 25,000 ft of wire cable was laid in less than an hour's flying time by a helicopter for the Hawaiian Electric Corporation over mountainous terrain on the island of Oahu.

Flight performance. Due to an incomplete understanding of the flight principles involved, many believe the helicopter capable of performing flight in any direction under any load or flight conditions. Like other aircraft, different helicopters possess different flight characteristics, but all 'copters have rotating airfoils producing lift. This lift can be varied both in magnitude and direction by the movement of the airfoil surfaces, and by "tilting" the lift component in the direction desired, travel in that direction is accomplished. For helicopters with a single main rotor, a small tail rotor is added to counteract engine torque.

A puzzling thought to some may be what happens to the helicopter should the engine fail. A "free-wheeling" unit in the transmission allows the rotors to remain turning even though the power may stop, and to keep the momentum built up in the system the pilot decreases altitude rapidly, reversing the flow of air through the rotor system. This "Chinese top" principle lends enough kinetic energy to the rotor blades that the pilot is able to use the rotational momentum stored in the system to make a normal landing. This forced landing procedure is called "autorotation."

The Author

George E. Tarbox is an exploration geophysicist in the Mid-Continent area for Stanolind Oil and Gas Company at Oklahoma City. He was graduated in 1952 from the Colorado School of Mines with a degree in geophysical engineering and joined Stanolind at that time. From early 1953 to March, 1955, he was a U. S. Army pilot engaged in topographic mapping in the U. S., Alaska and Hawaii. He served as both fixed-wing and helicopter pilot, helicopter maintenance officer and flight commander, and now holds civilian commercial licenses, including those for the Hiller, Bell and Sikorsky helicopters.

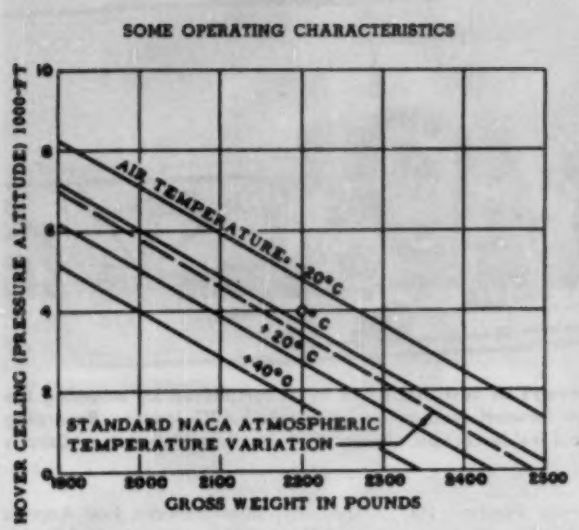

FIG. 1. **Hovering ceiling** when out of ground effect (Hiller 12B used).

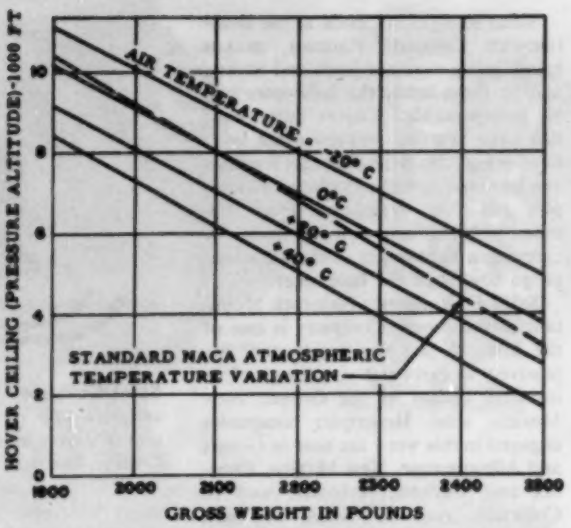

FIG. 2. **Effect of temperature** on hovering ability of the copter, using a Hiller 12B.

In discussing performance, only helicopters now in commercial operation will be considered; larger cargo-carrying craft are now becoming available as military requirements are met, and their larger capacity will reduce future costs substantially. The flying characteristics of the three helicopters in question (Bell, Hiller, Sikorsky) do not vary widely if one takes into account the greater load-carrying capacity of the Sikorsky.

When fully loaded at sea level, maximum flight speed ranges from 90 mph for the Bell and Hiller to 110 mph for the Sikorsky; minimum speed would depend upon temperature. Fig. 2 above illustrates the adverse effect of high temperature upon hovering ability. The chart was obtained using a Hiller 12B (weight with pilot only is 1945 lb, with gross load, 2500 lb).

"Ground effect," present only when the helicopter is within several feet of the ground, is due to the cushioning effect of greater air density provided by "packing" the air between rotors and the ground. Fig. 1, also using a Hiller 12B, shows the hovering ceiling when out of ground effect. It is easily seen that any condition such as high temperatures or high altitudes which lowers air density seriously reduces the capabilities of the aircraft.

Wind in amounts greater than 10-15 mph can also boost performance by providing a "translational" lift caused in part by the streamlining of the air flow through the system.

Service ceiling, with pilot only, is approximately 15,000 ft above sea level for the two smaller aircraft whereas the S-55 is limited to 11,400 ft. Addition of supercharge blowers can raise the first figure to as much as 18,000 ft.

When cargo is carried, performance drops accordingly; as a rule of thumb, the addition of maximum cargo cuts the practical "working ceiling" almost by half. As a result, any type of cargo-carrying above altitudes of 5000-8000 ft presents considerable difficulty, particularly in high-temperature areas.

Cargo capacity for the Hiller is approximately 550 lb, for the Bell, 600 lb, and for the Sikorsky S-55, 1800 lb. The latter aircraft is able to carry eight passengers in addition to the pilot; the two smaller 'copters are three-place. The reason for the slightly smaller payload of the Hiller (which has the same engine and rotor blades as the Bell) is due to the added weight of an electrically-operated trim control which helps to prevent pilot fatigue. A similar "servo" system is standard on all larger helicopters, including the S-55.

Range of the Hiller is approximately 125 miles at 60 mph, without auxiliary gas tanks. The Bell, due to slightly larger tanks, can travel 150 miles without refueling, while the Sikorsky is able to operate up to 350 miles at 85 mph.

Instrument flight with helicopters as they are equipped today is hazardous at best. Future 'copters will contain navigation and orientation equipment especially designed for the purpose, but present equipment in the Bell and Hiller makes "blind flying" impossible; the Sikorsky can fly on instruments only for short periods of time.

Cost. Initial cost of the Bell and Hiller models is approximately the same and depends upon availability, accessory equipment and number desired. Prices can vary from $35,000-$40,000 for the Hiller 12B, 12C and the Bell 47G to $42,000 for the higher-powered Bell 47G-2. Cost of the Sikorsky S-55 fluctuates in the $150,000-$200,000 range, depending upon equip-

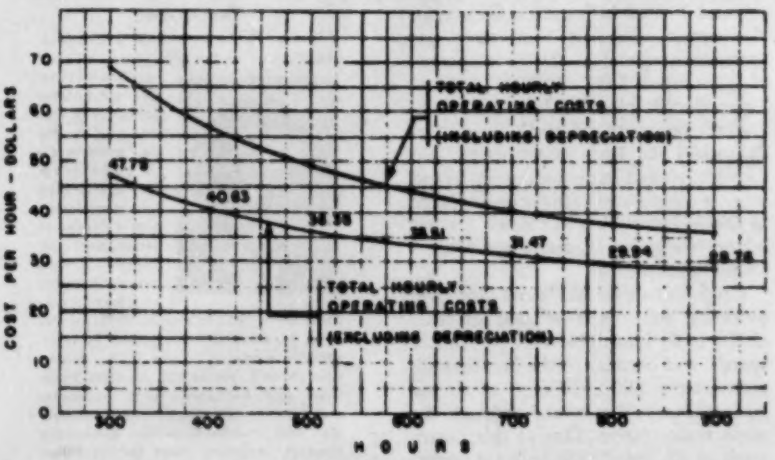

FIG. 3. **Operating costs** per hour at different usage levels for the Hiller 12B.

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ment. First deliveries of the new Sikorsky S-58 will be about $250,000 apiece. Shown below is an estimated capital requirement for a single Bell model 47G-2 operation:

Bell Model 47G-2 helicopter in standard configuration	$37,780.00
Night flying equipment, installed	$ 472.98
LTR-6 Radio, installed	$ 550.00
Set of Special Helicopter Tools (est.)	$ 3,570.00
Helicopter Spare Parts and Spare Parts in reserve depends on type operation and location. For planning purposes use arbitrary figure which can be adjusted up or down	$ 1,000.00
	$43,442.98

Operating costs. Operating costs cover a wide range and depend upon number of hours flown, type of operation, whether maintenance is sub-contracted, and a number of other factors (salt water corrosion problems, high altitudes, etc.). Operating expenses for New York Airway's S-55's average 73¢/available seat-mile (for five passengers); this compared to the passenger fare of 35¢/mile. The existing high costs of operating the S-55 are due for the most part to the following factors: (1) the helicopters being used today were designed and built to satisfy military requirements in which economics is secondary and as a result (2) passenger and cargo space cannot always be fully utilized, even in converted commercial versions of military models.

Fig. 3 illustrates the annual hourly cost at different usage levels for the Hiller 12B, with pilot salary, insurance and hangarage amounting to about one-third of the total shown; parts, fuel and maintenance account for the bulk of the remainder.

A breakdown of operating costs is shown in Table 1.

It must be remembered that these figures are merely an average value and could be higher or lower for any particular operation. For example, pilot salary covers a $5500-$9500 bracket depending on locale, flight experience, etc., and therefore a salary of $7200 is assigned. The maintenance labor cost of $4.50 per man-hour should cover mechanic's wages plus overhead or established contract helicopter maintenance charges if the work is subcontracted. Time spent for maintenance for smaller helicopters is broken down in Table 2 and generally runs about 1.6 man-hours per flying hour, including inspections, engine changes and test flights.

TABLE 2. Maintenance functions for 700 hours flight per year.
(based on 200 days flying at 3½ hours per day)

Functions	Man-hours required
200-Daily Inspections	200
21 -35 Hour Inspections (3 per 100 hours)	84
5 -100 Hour Inspections	40
1 -300 Hour Inspection	35
1 -600 Hour Inspection	300
5 -Test Flight Adj. after 100 Hr. Insp.	12½
1 -Test Flight Adj. after 300 Hr. Insp.	3½
1 -Test Flight Adj. after 600 Hr. Insp.	6
2 -Engine Changes (at 300 and 600 Hrs.)	32
Miscellaneous Trouble Shooting and Repairs	400
Total Man-Hours	1113

Note: Inspections vary as to different models, and are slightly less for Bell 476-2.

Average engine overhaul cost for Aircooled Motors, Inc., installation in most of the Bell and Hiller craft is $713.07 every 300 flying hours, amounting to $2.38 per flying hour. This period is now up to 600 hours for the new models. Overhauls are also less frequent for the Pratt and Whitney radial engine in the S-55 although the cost is approximately 50 per cent higher.

TABLE 1. Operating cost (estimated) Hiller UH-12B.

	FLIGHT HOURS PER YEAR						
	200	400	500	600	700	800	900
FIXED COSTS:							
Pilot	$ 7,200	$ 7,200	$ 7,200	$ 7,200	$ 7,200	$ 7,200	$ 7,200
Wages, Taxes & Comp. Ins.	347	347	347	347	347	347	347
Insurance — PL & PD	750	750	750	750	750	750	750
Hangarage	250	250	250	250	250	250	250
Sub-Total	8,547	8,547	8,547	8,547	8,547	8,547	8,547
VARIABLE COSTS:							
Fuel	1,404	1,872	2,340	2,808	3,276	3,744	4,212
Oil	78	104	130	156	182	208	234
Maintenance-Labor ($4.50/hr.)	2,160	2,880	3,600	4,320	5,040	5,760	6,480
Engine Major Overhaul-Labor	450	600	750	900	1,050	1,200	1,350
Aircraft Parts	1,275	1,700	2,125	2,550	2,975	3,400	3,825
Engine Parts	261	348	435	522	609	696	783
Supplies	150	200	250	300	350	400	450
Sub-Total	5,778	7,704	9,630	11,556	13,482	15,408	17,334
Total Operating Cost	14,325	16,251	18,177	20,103	22,029	23,955	25,881
Cost Per Hour	47.75	40.63	36.35	33.51	31.47	29.94	28.76
DEPRECIATION:							
Helicopter (5 year base)	6,012	6,012	6,012	6,012	6,102	6,012	6,012
Cost Per Hour	20.40	15.03	12.03	10.02	8.50	7.52	6.68
Total Cost Per Hr.-Incl. Depreciation	68.15	55.66	48.49	43.53	40.06	37.46	35.44
OPERATING COST — LESS PILOT:							
Pilot's Salary	7,200	7,200	7,200	7,200	7,200	7,200	7,200
Wages, Taxes & Comp. Ins.	347	347	347	347	347	347	347
Total	7,547	7,547	7,547	7,547	7,547	7,547	7,547
Pilot Cost Per Hour	25.16	18.87	15.09	12.58	10.78	9.43	8.39
Total Cost Per Hour — Less Pilot	44.19	37.96	34.22	31.73	29.95	28.61	27.57

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For example, one company drilled three wells to an average depth of 8,200 feet each in the same offshore field, using Du Pont CMC in one and refined CMC in the other two. Mud costs with Du Pont CMC were $2.12 per foot, while costs in the other two wells were $4.30 and $4.17, respectively. Fluid-loss control was comparable for the three wells and the excessive mud viscosity commonly incurred with refined CMC was not encountered in the well using Du Pont CMC.

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by Allen Woolf, Toolpusher, Rig #11 • Woolf & Magee Drilling Contractors, Tyler, Texas

WHEN you can drill 71,000 feet of hole and ream another 30,000 without replacing mud valve parts you have good mud valves. Our Rig #11, completely equipped with Rockwell-Built Edward MUDWONDER mud valves, made this record of over 100,000 feet and continued to operate without mud valve repairs.

MUDWONDER cut-away view shows the double thread construction, separated stainless stem and hard chromed gate with "T" slot connection and the one-piece seat insert with the buna-N molded integrally over the steel wear rings.

Economy is the watchword in slim hole drilling and the MUDWONDER certainly has proved economical for every slim hole service whether on the standpipe, fill-up or release line.

Since we installed MUDWONDER valves downtime and repair costs have been cut greatly. In fact, mud valve downtime has been zero. No parts have been replaced and no valves have failed.

Besides solving maintenance problems, these MUDWONDER valves solved another problem encountered from time to time, especially in the Louisiana area where Rig #11 has been drilling. Sanding up of valves has always caused trouble in this area but, even with extremely high sand content mud, the Mudwonder has never failed to operate. It always opens or closes easily regardless of the pressure.

I can recommend MUDWONDER to any toolpusher having mud valve trouble. MUDWONDER valves are built in 2", 3", and 4" sizes with screwed or flanged ends for 2000 psi WP (4000 psi test) and 3000 psi WP (6000 psi test).

See your favorite oil field supplier for complete information, or write Edward Valves, Inc., East Chicago, Indiana. Quick shipments can be made from East Chicago or the Edward warehouse in Houston through the supply store you select.

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As mentioned previously, the Bell 47G and the Hiller 12B have identical power and rotar blade units, with the main differences being in fuselage construction, control systems and accessory drives. For this reason, costs shown in Tables 1 and 2 can be used for either of the two aircraft.

Insurance: Liability and property-damage insurance is $750 to $1000 per aircraft per year, depending upon aircraft size, and varies from 1¢ to 5¢ an acre for agricultural operations such as seeding and dusting. Because of its high cost, hull insurance is normally not carried by present operators. However, hull insurance of various kinds can be obtained at an annual rate of from 10 to 20 per cent of the initial valuation of the helicopter.

Future developments. Hindering commercial growth of the helicopter are two main factors: (1) all present production is basically designed with military specifications in mind, and the bulk of production goes in that direction; and (2) cost due to semi-custom building and rapid development after long research, is still high. However, the manufacturers have an eye to the future, and tomorrow's helicopter will be more readily available, better fitted for commercial tasks and less costly.

Present small utility 'copters are being improved by Bell and Hiller (250-hp engine, four-place, greater speed and payload), and Cessna's new CH-1, able to hover at 11,000 ft with gross load, will be in production soon. Sikorsky and Piasecki have twin engine transport helicopters now becoming available for transport service; of these, Sikorsky's S-56 could carry 35 passengers with derated Allison engines delivering 3200 eshp. This craft, if equipped with turbines, would lift more than its present 3-ton payload, and may be ready by 1959. The Piasecki YH-16A weighs more than 16 tons, is 80 ft long, and can accommodate 40 passengers with ease. Employing shaft turbines, it recently set records of 166 mph and 24,500 ft altitude. Such a craft would be able to carry drilling crews and parts to offshore rigs in a single trip, and the multi-engine feature would add to greater safety and dependability. Its use to exploration parties, such as seismograph crews, would be invaluable.

As future developments in helicopters become available, more and more industries will find that they, too, will be able to afford the versatile services of the whirlybird. The petroleum industry has truly found a new tool for its many phases of exploration which will become even more useful in the years ahead. * * *

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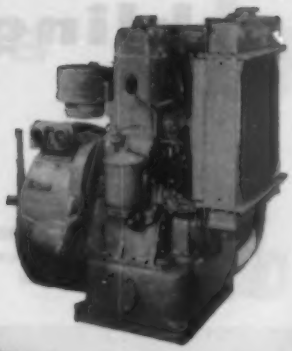

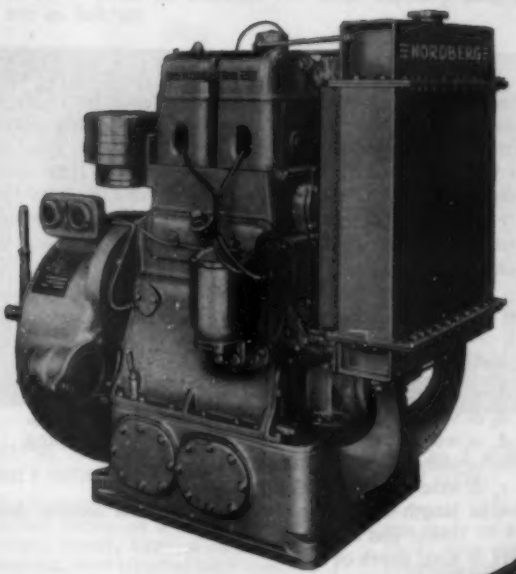

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Formula Developed to Determine . . .

Buckling of Oil Well Piping

Tendency of cemented casing to buckle not only depends on changes of conditions after cementing, but also on conditions prevailing when the cement sets. A new criterion. . . . . and some examples of its use

C. A. Bouman
N. V. de Bataafsche Petroleum Maatschappij, The Hague, Holland

A general formula is developed for evaluating the tendency of both free hanging oil well piping and cemented casing strings to buckle. It appears that the influence of pressure and temperature changes after cementing casing, the method of landing and the depth of the cemented section of a casing easily can be accounted for in the formula.

The present method of deriving a general buckling criterion is based on direct equilibrium considerations without using the intermediate linkage of absolute tension or compression stresses in the oil well piping.

When assuming infinite slenderness of the piping, the buckling criterion for a free hanging casing can be derived in a simple way. However, another approach to this problem was considered desirable as an introduction to the buckling problem of the cemented casing. The buckling criterion for the cemented casing has also been derived in two different ways.

Buckling Criterion for Free Hanging Pipe

It will first be assumed that, as shown in Fig. 1, the casing or tubing considered is completely filled with liquid with a constant weight per unit volume d_i and that the material outside the piping consists of a liquid with a constant weight per unit volume d_e. Values of d_i and d_e may be different.

Taking into consideration that the pipes considered are very slender, it may be stated that no tendency to buckling will exist if the weight of the pipe and the liquid in the pipe below any cross section such as 1-1, exceeds the weight of the outer fluid displaced by the pipe below said cross section. In other words, if the total force resulting from pipe weight (downward), weight of inner fluid (downward), and displaced weight of outer fluid (upward), *all calculated below a certain cross section*, is a downward force, this downward force will cause a straightening action in said cross section and there will be no tendency to buckling.

Thus, to avoid buckling, the criterion:

$$l[d_s (A_e - A_i) + d_i A_i - d_e A_e] > 0 \quad . \quad . \quad (1)$$

should be satisfied.

d_s = weight per unit volume of steel.
d_i = weight per unit volume of liquid inside piping.
d_e = weight per unit volume of liquid outside piping.
r_i = internal radius of pipe; $\pi r^2_i = A_i$
r_e = external radius of pipe; $\pi r^2_e = A_e$
l = length of piping from certain cross section down to lower end of string.
H = total depth of well.

In the case of different values of d_i and d_e it is assumed that the pipe string is closed at the bottom, or in certain other ways (by exertion of pressure) allows a difference in fluid density inside and outside the piping.

The above-mentioned expression, in general, requires a mathematical proof (Biezeno and Koch, reference 1). However, in the case of slender pipes it can be proved as follows.

It has been explained by several authors (2) (3) that the tendency to buckling of free hanging pipe strings is not influenced by any superimposed *constant* internal or external pressure acting on the pipe. In point of fact, the bending moment in a cross section of the free hanging pipe resulting from a constant internal or external pressure below the said cross section is zero. This is easily proved by observing that the only additional stresses in said cross section, required for the equilibrium of the part of the piping considered must be equivalent to a constant pressure equally distributed over the area A_i (or A_e) of the cross section of the pipe. Said hypothetical constant pressure is equal to the superimposed constant pressure.

Applying this result in the case of the pipe string with its lower end free, the tendency to buckling of the string below a certain cross section 1-1 will not change if the following constant pressures are added to, or better, subtracted from the system:

a. a constant pressure equal to the liquid pressure inside the pipe at said cross section 1-1 is subtracted from the liquid pressures inside the pipe.

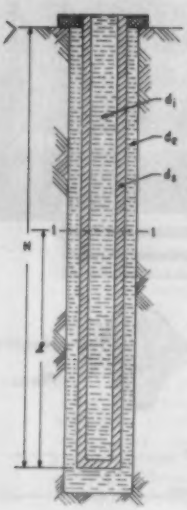

FIG. 1. **Free hanging pipe filled with liquid. Liquid outside pipe may have a different density.**

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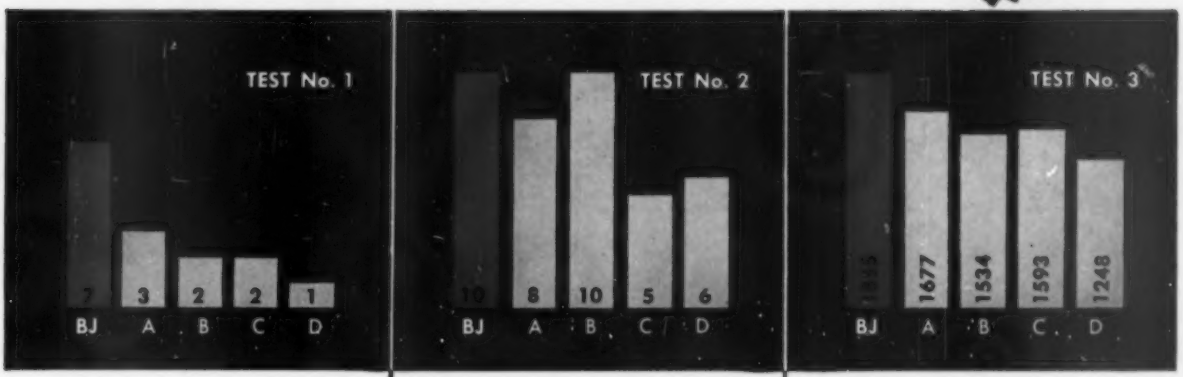

TEST NO. 1. NUMBER OF BLOWS TO SHEAR TEETH:

The testing machine produced heavy impact blows on a single tooth. These blows, kept at constant strength, were repeated until shearing took place.

TEST NO. 2. NUMBER OF BLOWS TO SPALL TEETH:

A series of heavy impact blows was made on a single tooth. These blows were repeated until spalling (chipping) took place. A rating of 10 indicates no spalling.

TEST NO. 3. FT-LBS IMPACT PER ROW TO CAUSE FAILURE:

Impact effect on a row of teeth rather than on a single tooth was studied. The ft-lbs impact force necessary to make each die unfit for use was recorded.

BJ engineers designed this tong die testing machine to measure impact and shear strength. A hydraulic piston applies radial, tangential and impact forces which are accurately measured by precision pressure gages.

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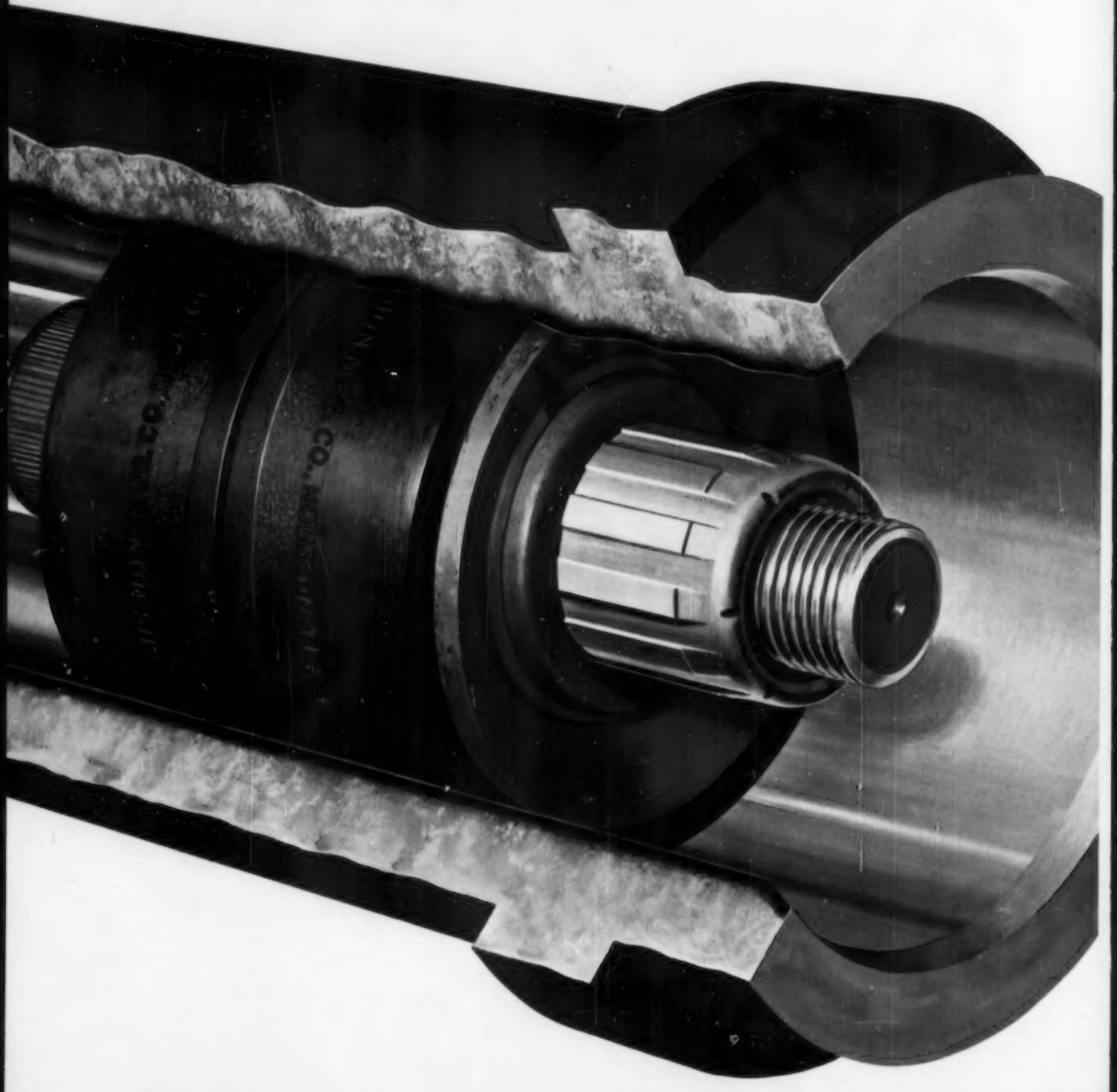
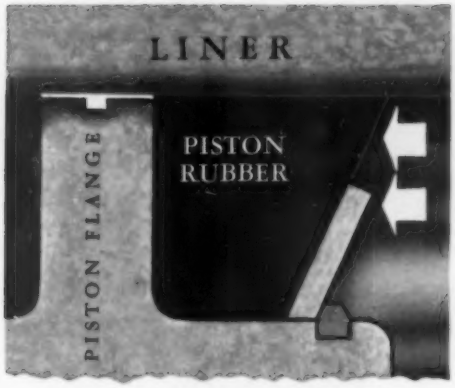
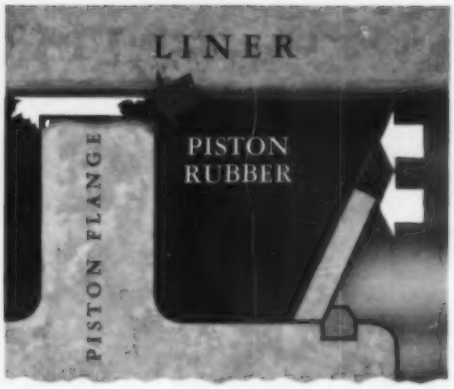




When liner and piston flange fit closely, pressure can not extrude rubber into the clearance to be pinched off. A close fit between piston and liner eliminates the main cause of piston failure and greatly extends piston life.



An important cause of piston failure is excessive clearance between the piston flange and liner. When pump is operating, pressure forces a part of the piston rubber between the space where it is pinched off. This action seriously shortens piston rubber life.

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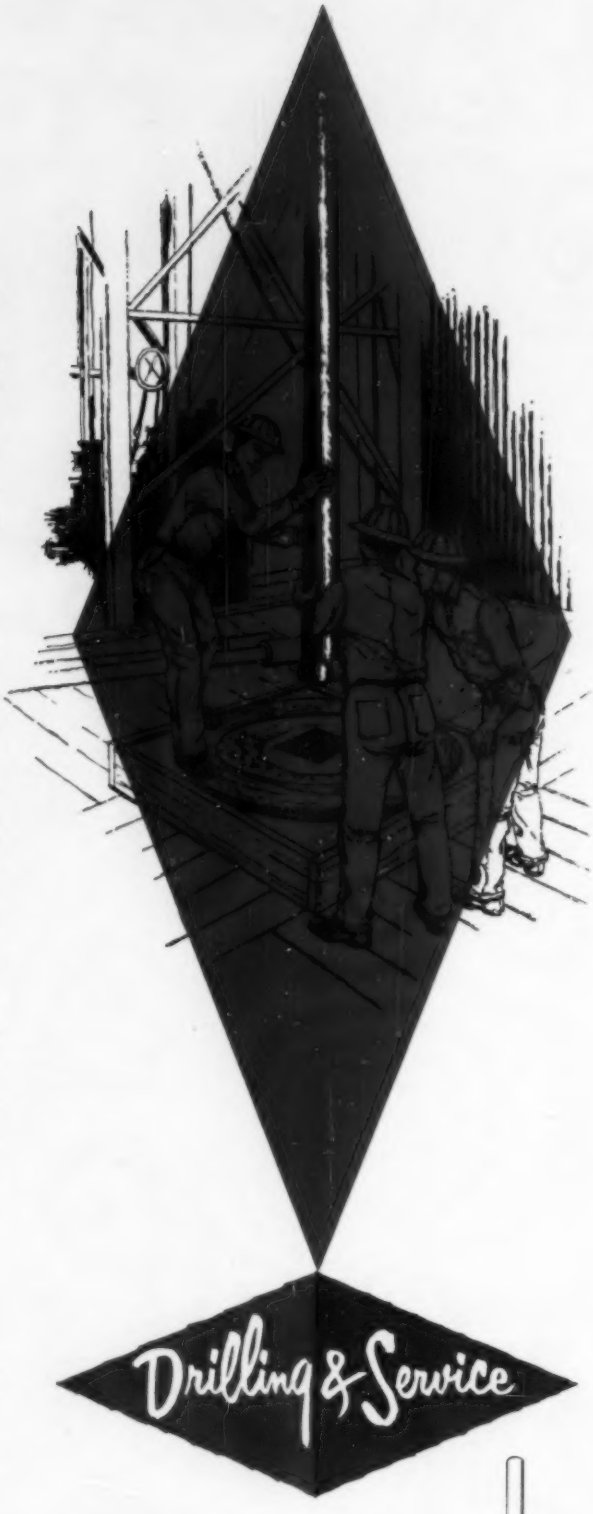

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b. a constant pressure equal to the liquid pressure outside the pipe at cross section 1-1 is subtracted from the liquid pressures outside the pipe.

As a consequence of these subtractions, the piping *below the cross section* 1-1 will be subjected to the following liquid pressures:

Inside: liquid pressure increasing linearly from zero to $d_i l$.

Outside: liquid pressure increasing linearly from zero to $d_e l$.

In regard to the tendency to buckling, this theoretical system (subjected to reduced pressures) is equivalent to the actual system for which liquid pressures increase linearly from d_i (H-l) to $d_i H$ and from d_e (H-l) to $d_e H$, respectively.

If the pipe string subjected to the reduced pressures is given a small lateral deflection, the forces resulting from pipe weight, weight of inner fluid and weight of displaced outer fluid will still pass through the center of gravity of that part of the pipe below the cross section 1-1 considered. Therefore, if the total resulting force has a downward direction, there will occur a straightening moment and there will be no tendency to buckling. This is the statement given at the beginning of this paragraph (equation 1).

Evidently, equation (1) can be written:

$$d_s(A_e - A_i) + d_i A_i - d_e A_e > 0 \quad . \quad . \quad . \quad (2)$$

It should be added that as the pipe size is increased, the safety margin will be greater than that calculated with the aid of equations (1) or (2).

In the above, it was assumed that the piping below the cross section considered was completely filled with liquid with weight per unit volume d_i. It will now be assumed that the lower part (length l_1) of the piping is filled with liquid and that a cross section 2-2 (see Fig. 2) at a distance l from the bottom of the well ($l > l_1$) is considered. In this case, the force resulting from the weight of the inner liquid may *not* pass through the center of gravity of the pipe below the cross section 2-2 when the pipe string is given a small lateral deflection. Depending on the type of deflection given to the system in the well, lateral displacement of the center of gravity G_1 of the inner fluid (see Fig. 2) may be larger or smaller than the lateral displacement of the center of gravity G of the pipe. However, this difference may be neglected in the case of slender oil well piping, so that the criterion for the tendency to buckling will again be given by the direction of the total resulting force as follows:

$$l[d_s (A_e - A_i) - d_e A_e] + l_1 d_i A_i > 0 \quad . \quad . \quad (3)$$

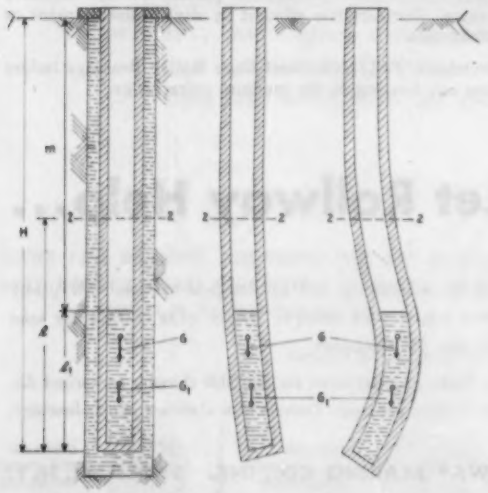

FIG. 2. **Partially filled** free hanging pipe, showing the effects of varying lateral deflections.

If equation (3) becomes zero at a certain cross section, the piping will tend to buckle somewhere *above* this section (top buckling).

The Drilling String

To reduce the tendency to buckling of drill pipe as a consequence of the loads exerted by the bit during drilling, drill collars are applied. Weight of the drill collars plus the weight of the bit minus the weight of the drilling mud displaced by drill collars and bit should be larger than the maximum force exerted by the bit.

For the rest, the tendency to buckling of the drilling string *above* the drill collars should be examined with the aid of equations (2) or (3). If criterion (2) applies, buckling will usually not occur.

If criterion (3) applies buckling or bending at the top of the string may occur but excessive deformations might be prevented by the surrounding formation or by the upper casing.

If it is necessary to use the expression "neutral zone", this should be defined as the cross section in the drill collar string below which the weight in mud of the drill collars equals the drilling weight (bit force).

It should be emphasized that the tendency to buckling of the *drill collar string* is *not* studied in this paper.

Influence of Liquid Pressure on Walls of Free Hanging Pipe

Although the buckling criterion equation (1) or (2) for a free hanging casing can be obtained in a relatively simple way, another method for developing this criterion may appear to be useful for a better understanding of the buckling problem.

With this method, it will be assumed that the free hanging piping is given a small lateral deflection (see Fig. 3) and the influence of liquid pressures on the internal and external surface of the piping below a certain cross section ($x = 0$) will be investigated under these conditions.

At a distance x below the said cross section, liquid pressures on internal and external surface of a ring element between two horizontal planes at distance dx will amount to $(p_{io} + d_i x)$ and $(p_{eo} + d_e x)$, respectively.

p_{io} = internal liquid pressure at cross section ($x = 0$).
p_{eo} = external liquid pressure at cross section ($x = 0$).
d_i = weight per unit volume of liquid inside piping.
d_e = weight per unit volume of liquid outside piping.

An enlarged cross section of the pipe element under consideration is shown in Fig. 3.

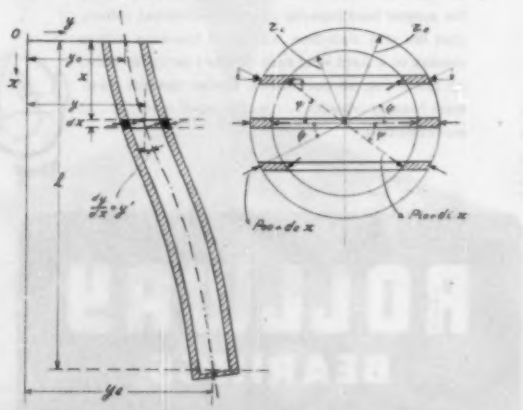

FIG. 3. **Influence of liquid pressures** on internal and external surfaces below a certain cross-section of a free hanging pipe.

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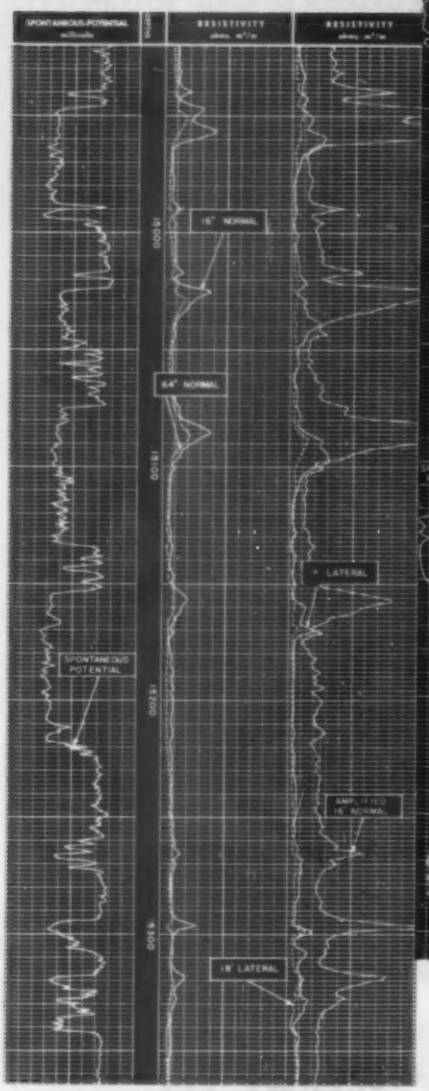

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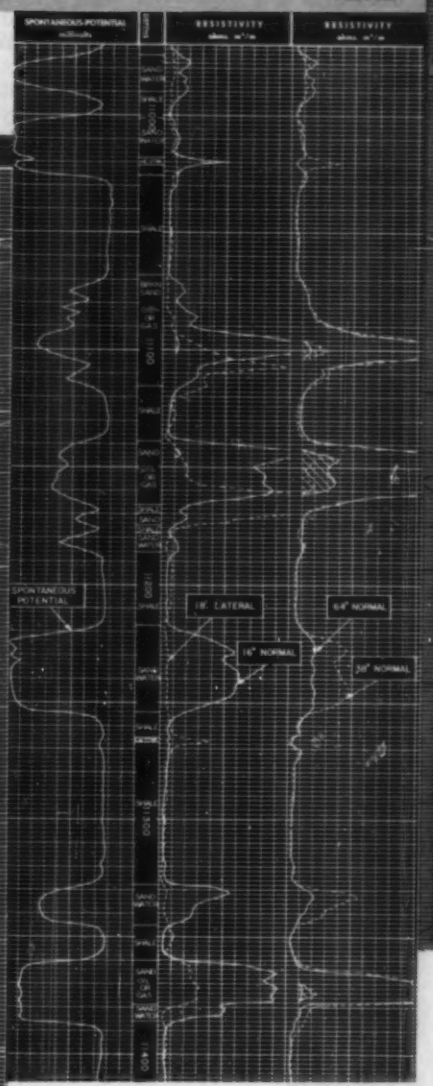

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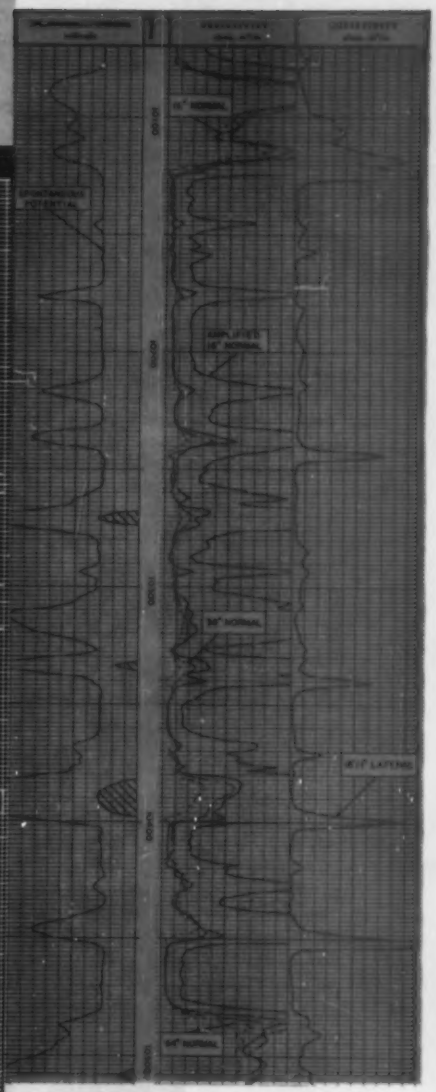

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The ring element can be subdivided into small vertical strips parallel to the plane in which bending of the pipe axis is supposed to occur.

For the strip through the pipe axis ($\Phi = 0$, $\Psi = 0$) the liquid pressures on internal and external surfaces result in a small bending moment which will amount to:

$$r_e d\varphi\, dx\, (p_{eo} + d_e x)\, 2\, r_e y' - r_i d\Psi\, dx\, (p_{io} + d_i x) \cdot 2 r_i y' = \\ = [\, (p_{eo} + d_e x)\, dA_e - (p_{io} + d_i x)\, d\, A_i\,]\, y' dx$$

For any strip (angles φ and Ψ respectively) a similar formula, which introduces factors $\cos^2\varphi$ and $\cos^2\Psi$, applies.

Consequently, the total bending moment d M_1 exerted by liquid pressures on a ring element at distance x will amount to:

$$d\ M_1 = [\, (p_{eo} + d_e x)\ A_e - (p_{io} + d_i x)\ A_i\,]\, y' dx$$

The bending moment M_1 in the cross section ($x = 0$), caused by liquid pressures on internal and external pipe walls between two horizontal planes ($x = 0$) and ($x = l$) will amount to:

$$M_1 = \int_o^l [\, (p_{eo} + d_e x)\, A_e - (P_{io} + d_i x)\, A_i\,]\, y'\, dx =$$

$$= (p_{eo}A_e - p_{io}A_i) \cdot \int_o^l dy + (d_e A_e - d_i A_i) \int_o^l x\, dy =$$

$$= (p_{eo}A_e - p_{io}A_i) \cdot (y_l - y_o) + (d_e A_e - d_i A_i)$$

$$\left\{ [xy]_o^l - \int_o^l y\, dx \right\} =$$

$$= (p_{eo}A_e - p_{io}A_i)\ (y_l - y_o) +$$

$$d_e A_e - d_i A_i)\ [l y_l - \int_o^l y\, dx\,] =$$

$$= (p_{eo}A_e - p_{io}A_i)(y_l - y_o) + (d_e A_e - d_i A_i) \int_o^l (y_l - y)\, dx.$$

By rearranging:

$$M_1 = [\, (p_{eo} + d_e l)\ A_e - p_{io} + d_i l)\ A_i] \, (y_l - y_o) \\ + (d_i A_i - d_e A_e) \int_o^l (y - y_o)\, dx \quad . \quad . \quad . \quad (4)$$

It should be observed that the resultant of the liquid pressures on internal and external pipe walls *between two horizontal planes* consists of a bending moment (M_1) only; any resultant force in any direction does not exist. On the other hand, it may be observed that the bending moment M_1 is *equivalent to* that of certain imaginary vertical forces with respect to the cross section ($x = 0$) which can easily be seen from the equation (4) and Fig. 3.

Liquid pressures on the internal and external surface of the piping (assumed to be closed at the bottom) below the horizontal plane ($x = l$) result in a *vertical downward* force equal to:

$$(p_{io} + d_i l)\ A_i - (\, p_{eo} + d_e l)\ A_e$$

The bending moment M_2 in the cross section ($x = 0$), caused by this downward force will amount to:

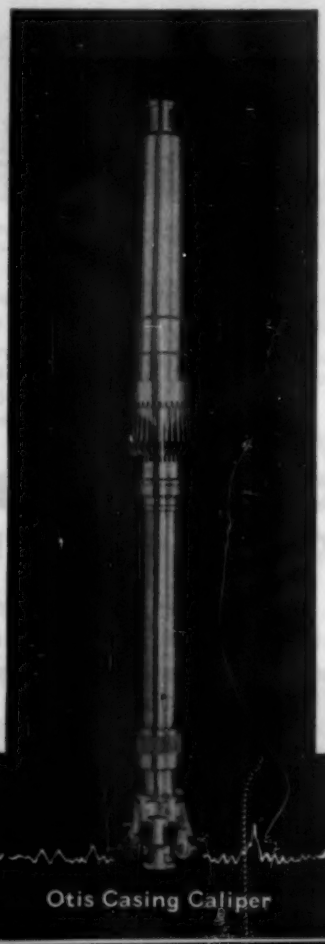
$$M_2 = [\, (p_{io} + d_i l)\ A_i - (p_{eo} + d_e l)\ A_e] \, (y_l - y_o)\, . \quad (5)$$

The bending moment M_l in the cross section ($x = 0$), caused by all liquid pressures on internal and external surfaces of the free hanging piping (assumed to be closed at the bottom) below the cross section ($x = 0$) will amount to:

$$M_l = M_1 + M_2 = (d_i A_i - d_e A_e) \int_o^l (y - y_o)\, dx\, . \quad (6)$$

The bending moment M_s in the cross section ($x = 0$), caused by the weight of the steel below the cross section ($x = 0$) will amount to:

$$M_s = \int_o^l d_s\, (A_e - A_i)\, (y - y_o)\, dx \quad . \quad . \quad . \quad (7)$$



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The total bending moment M in the cross section (x = 0) caused by the weight of the steel and by the liquid pressures will amount to:

$$M = M_l + M_a = [d_a (A_e - A_i) + d_i A_i - d_e A_e] \int_o^l (y - y_o)\, dx \quad . \quad . \quad . \quad . \quad (8)$$

If, for the case considered in Fig. 3, M has a positive value, there will be no tendency to buckling which means that criterion (2) should be satisfied in order to prevent the possibility of buckling.

Equation (8) confirms that the tendency to buckling of free hanging piping is not influenced by any superimposed constant internal or external pressure (p_{io} or p_{eo}) on the liquid in or around the pipe.

Buckling Criterion for Casing Before and After Cementing

Two different stages will have to be considered for the cemented casing, namely the stage *before* the cement has set and the stage *after* the moment the cement has set.

In the stage before the cement has set, the buckling criterion as given by equations (1) or (2) requires a modification because, in general, the weight per unit volume of the cement slurry (d_c) will be different from d_e. This influence may be significant in the case of long cement columns.

With the aid of a reasoning nearly identical to that given for free hanging pipe, the equilibrium relation (buckling criterion) for the casing as shown in Fig. 4 and as valid *before* the cement has set can be found.

For two different cross sections (3 — 3) and (4 — 4) below and above the cement top, respectively, the buckling criterion is:

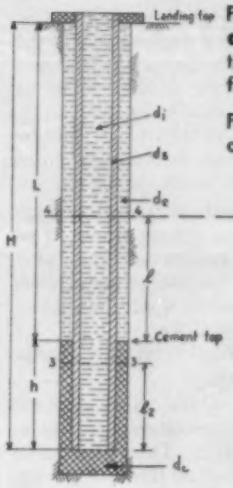

Fig. 4

FIG. 4. (Left) **Cemented casing analysis.** Equilibrium relations determine at sections 3-3 and 4-4 before and after cement has set.

FIG. 5. **Density relations** inside and outside a cemented casing.

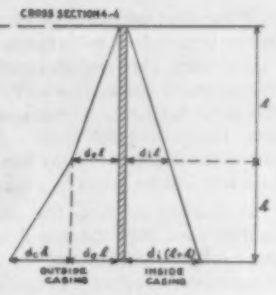

Fig. 5

a) Below the cement top:

$$d_a (A_e - A_i) + d_i A_i - d_c A_e > 0 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

b) Above the cement top (see also Fig. 5), if h is the depth of the cemented part of the casing:

$$(l + h)\, d_a (Ae - A_i) + (l + h)\, d_i A_i - (l\, d_c + h\, d_c) A_e > 0$$

or:

$$h [d_a (A_e - A_i) + d_i A_i - d_c A_e] + l [d_a (A_e - A_i) + d_i A_i - d_e A_e] > 0$$

. . . . . (10)

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A similar reserve as that for a partly filled piping (see Fig. 2) has to be made here. In fact, the lateral displacement of the center of gravity of the displaced cement slurry may be larger or smaller than the lateral displacement of the centers of gravity of displaced drilling mud and mud inside the casing.

It is assumed that the effect of these differences may be neglected in the case of slender casings. It is also assumed that practically no cement slurry is left inside the casing.

If the fluid pressures inside and outside the casing are kept at the same values as at the moment the cement has set, if no temperature changes occur after the cement has set, and if the casing is landed "as cemented", then the casing exhibits the same tendency to buckling as existed when the cement sets. That is, for any cross section at distance l ($0 < l < L$) above the cement top the buckling criterion will not change and will still be given by equation (10).

If changes occur in the conditions of the casing after the cement sets, then there will occur a simultaneous change in the buckling tendency of the casing string. These changes in conditions introduce changes in the load on the casing hanging assembly and introduce a force at the cement top.

It is assumed that the permanent freeze point of the casing is at the cement top. The vertical force exerted on the cement top by the casing must be taken into account when studying the tendency to buckling.

In view of the fact that the casing considered is very slender, the influence of bending moments and shearing forces at the fixed ends of the casing may be neglected.

The said vertical force at the cement top shall be called V (not to be confused with the vertical forces V and V′ mentioned in the 1951 Lubinski paper) and represents the vertical reaction force exerted by the cemented portion of the casing on the free part of the casing between cement top and landing top.

The value of V is positive if V has a downward direction. An extra reaction force V in opposite direction will, of course, be exerted by the landing top.

Apart from the vertical force V at the cement top there is also the possibility of an additional bending moment caused by additional fluid pressures on the walls of the casing. This additional bending moment would come into existence if the casing would have lateral deflections. It can be considered to be equivalent to the bending moment with respect to the cross section considered, exerted by a certain imaginary vertical force C. The value of C will be considered positive if C has a downward direction.

As a result of the additional correction C and of the additional force V, the equilibrium relation (10) will have to be modified by adding C and V as follows:

$$B = h\,[d_a\,(A_e - A_i) + d_iA_i - d_eA_e] + l\,[d_a\,(A_e - A_i) + d_iA_i - d_eA_e] + C + V > O \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (11)$$

Equation (11) gives the buckling criterion (B) for any cross section ($O < l < L$) of the casing between cement top and landing top. Equation (10) may be considered as a special case of equation (11), namely if $C = 0$ and $V = 0$.

Value of correction C will be calculated in the following section.

The force V in equation (11) will have to be calculated from the condition that the change in length which would occur in the free casing as a consequence of *changes* in fluid densities, in gas pressures and in temperatures *after* cementing must be balanced by the change in length as a consequence of force V. This force will also be influenced by the method of landing the casing at the top.

The various components of the force V will be calculated in following sections.

Influence of Liquid Pressures

To calculate the value of correction C, it will be assumed that the cemented casing is built in at the cross section ($x = l$) and is given a small lateral deflection (see Fig. 6). Influence of liquid pressures on the internal and external surface of the casing between a certain horizontal plane ($x = o$) and the horizontal built-in section ($x = l$) will be investigated.

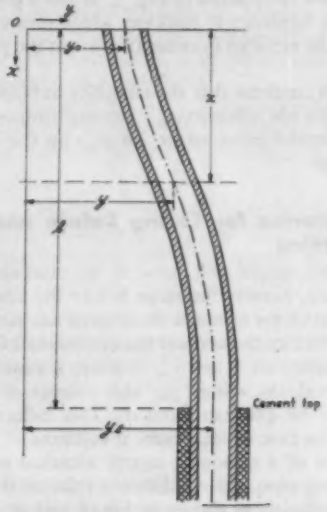

FIG. 6. **After cement has set,** influence of liquid pressures inside and outside the pipe is determined.

It is assumed that following changes in fluid pressures occur *after* cementing and landing of the casing.

Δp_i = increase of (gas) pressure on the liquid in the casing at its top.
Δp_e = increase of (gas) pressure on the liquid around the casing at its top.
Δd_i = increase of liquid density inside the casing.
Δd_e = increase of liquid density outside the casing.
Δp_{io} = increase of internal liquid pressure at cross section ($x = o$).
Δp_{eo} = increase of external liquid pressure at cross section ($x = o$).
$\Delta p_{io} = \Delta p_i + (L - l)\,\Delta d_i$.
$\Delta p_{eo} = \Delta p_e + (L - l)\,\Delta d_e$.

If it were assumed that the cemented casing would be a free hanging casing closed at the bottom (near the cement top) the term to be added in equation (1), in order to take into account the influence of the additional pressures mentioned above would be:

$$l\,(\Delta d_iA_i - \Delta d_eA_e)$$

Increased fluid pressures in and around the casing would cause an additional vertical force at the bottom of the free hanging casing. This vertical force (in upward direction) would amount to:

$$L\,(\Delta d_eA_e - \Delta d_iA_i) + \Delta p_eA_e - \Delta p_iA_i$$

No such additional force would act on the actual open cemented casing. Therefore, the correction to be applied for this force should be equivalent to a downward force of the same value.

Consequently, the terms to be added in equation (10) in order to take into account the *hydrostatic* influence of the *additional* fluid pressures on the actual open cemented casing should be as follows:

$$C = l(\Delta d_iA_i - \Delta d_eA_e) + L(\Delta d_eA_e - \Delta d_iA_i) + \Delta p_eA_e - \Delta p_iA_i \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (12)$$

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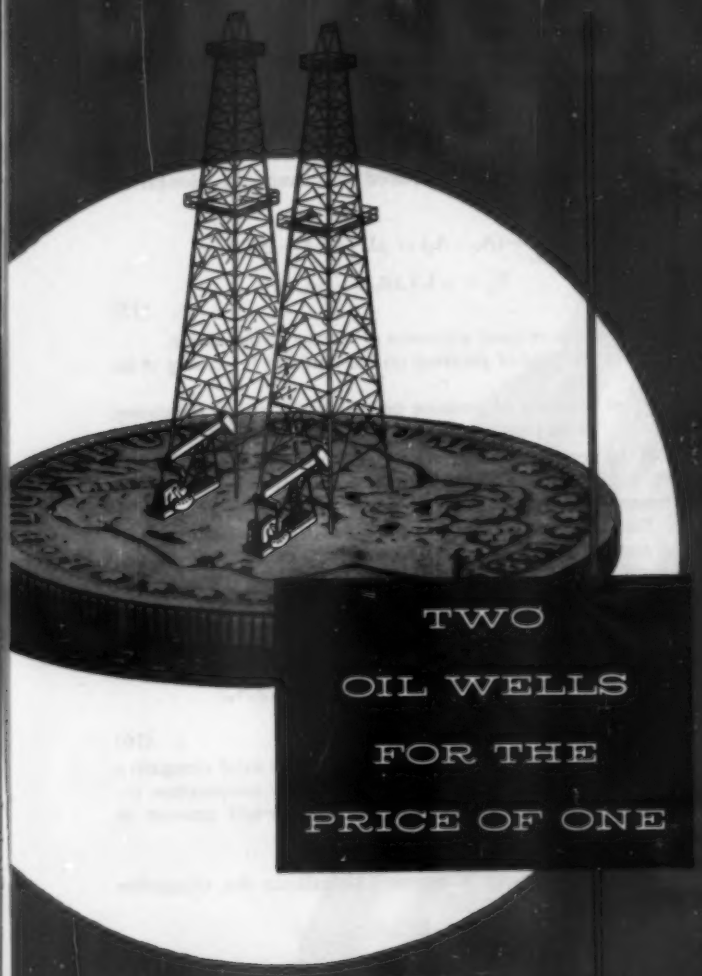

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Referring to Fig. 6, a more accurate equation of this influence would be as follows:

$$M_1 = [L(\Delta d_e A_e - \Delta d_i A_i) + \Delta p_e A_e - \Delta p_i A_i]\,(y_l - y_o) + (\Delta d_i A_i - \Delta d_e A_e)\int_o^l (y - y_o)dx \qquad (13)$$

The same result can, of course, also be obtained with the aid of equation (4).

The said increases of liquid pressures on the cemented casing will cause a bending movement M_1 in the cross section (x = o), the value of which is given by equation (4), if p_{lo}, etc., are replaced by Δp_{lo}, etc.

$$M_1 = [(\Delta p_{eo} + \Delta d_e l) A_e - (\Delta p_{io} + \Delta d_i l)\, A_i]\,(y_l - y_o) + (\Delta d_i A_i - \Delta d_e A_e)\int_o^l (y - y_o)dx$$

By substitution of the values of Δp_{lo} and Δp_{eo}:

$$M_1 = [\,(\Delta p_e + L\Delta d_e)\, A_e - (\Delta p_i + L\Delta d_i)\,(A_i]\,(y_l - y_o) + (\Delta d_i A_i - \Delta d_e A_e)\int_o^l (y - y_o)dx$$

or, by re-arranging:

$$M_1 = (\Delta d_e A_e - \Delta d_i A_i)\, L\, (y_l - y_o) + (\Delta p_e A_e - \Delta p_i A_i)(y_l - y_o) + (\Delta d_i A_i - \Delta d_e A_e)\int_o^l (y - y_o)dx \qquad (13)$$

This is again the equation (13) derived in another way. As mentioned already, the resultant effect of the increased liquid pressures on internal and external casing walls between the two horizontal planes (x = o) and (x = l) consists of a bending moment only. According to equation (13) this bending moment may be considered as being equivalent to the bending moment with respect to the cross section (x = o) exerted by the following imaginary forces:

$$C_1 = L(\Delta d_e A_e - \Delta d_i A_i)$$
$$C_2 = \Delta p_e A_e - \Delta p_i A_i$$
$$C_3 = l(\Delta d_i A_i - \Delta d_e A_e)$$

C_1 and C_2 are imaginary forces acting downward at the cement top,

C_3 is an imaginary force equally distributed along the axis of the casing.

$C = C_1 + C_2 + C_3$ (see also equation (12), above) which means that the more accurate equation (13) is replaced by equation (12).

In regard to the influence of increased liquid pressures, the present findings confirm Lubinski's results. For example, replacing the fluid inside a casing by a heavier one increases the tendency to buckling, mainly in the bottom part of the casing.

The value of C being known, the general buckling criterion (11) can be expressed as follows:

$$B = h[d_e(A_e - A_i) + d_i A_i - d_e A_e] + l[d_e(A_e - A_i) + (d_i + \Delta d_i)A_i - (d_e + \Delta d_e)A_e] + L(\Delta d_e A_e - \Delta d_i A_i) + \Delta p_e A_e - \Delta p_i A_i + V > O \qquad (14)$$

It shows that the tendency to buckling of a cemented casing not only depends on changes of conditions after cementing but also on the conditions prevailing at the moment the cement is setting.

Vertical Forces Due to Changes After Cementing

1. *Change in weight per unit volume of liquids.*

Δd_i = increase of internal liquid weight per unit volume.

Δd_e = increase of external liquid weight per unit volume.

If the cemented casing were free, an elongation of the casing would occur as a consequence of tangential and radial stresses caused by these changes in weight per unit volume.

At a distance x from the top of the casing (considered as a thick walled cylinder), the additional tangential stress σ_t and radial stress σ_r are:

$$\sigma_t = \frac{\Delta d_i \times r_i^2}{r_e^2 - r_i^2}\cdot\frac{r^2 + r_e^2}{r^2} - \frac{\Delta d_e \times r_e^2}{r_e^2 - r_i^2}\cdot\frac{r^2 + r_i^2}{r^2}$$

$$\sigma_r = \frac{\Delta d_i \times r_i^2}{r_e^2 - r_i^2}\cdot\frac{r^2 - r_e^2}{r^2} - \frac{\Delta d_e \times r_e^2}{r_e^2 - r_i^2}\cdot\frac{r^2 - r_i^2}{r^2}$$

Elongation in an axial direction at depth x as a consequence of the stresses σ_t and σ_r would amount to:

$$\varepsilon_a = -\frac{\mu}{E}(\sigma_t + \sigma_r) = -\frac{2\mu}{E}\frac{\Delta d_i r_i^2 - \Delta d_e r_e^2}{r_e^2 - r_i^2}\cdot x$$

where:

E = Young's modulus for steel.

μ = Poisson's ratio for steel.

The total elongation in an axial direction from landing top to cement top would amount to:

$$\Delta L = \int_o^L \varepsilon_a\, dx = -\frac{\mu}{E}\frac{\Delta d_i r_i^2 - \Delta d_e r_e^2}{r_e^2 - r_i^2}\cdot L^2$$

The component of V required to balance this elongation amounts to:

$$-\frac{E\,\Delta L}{L}(A_e - A_i) = \mu L\,(\Delta d_i A_i - \Delta d_e A_e)$$

$$V_1 = \mu\, L\,(\Delta d_i A_i - \Delta d_e A_e) \qquad (15)$$

2. *Change of (gas) pressures at the top of the casing.*

Δp_i = increase of pressure on the liquid in the casing at its top.

Δp_e = increase of pressure on the liquid around the casing at its top.

If the cemented casing were free, an elongation of the casing would occur as a consequence of tangential and radial stresses caused by the said changes in (gas) pressure.

The axial strain in the casing as a consequence of tangential and radial stresses caused by the gas pressures Δp_i and Δp_e would amount to (see also paragraph 1 above):

$$\varepsilon_a' = -\frac{\mu}{E}(\sigma_t' + \sigma_r') = -\frac{2\mu}{E}\frac{\Delta p_i r_i^2 - \Delta p_e r_e^2}{r_e^2 - r_i^2}$$

The part of V required to balance this strain amounts to:

$$-\varepsilon_a' E\,(A_e - A_i) = 2\mu\,(\Delta p_i A_i - \Delta p_e A_e)$$

$$V_2 = 2\mu\,(\Delta p_i A_i - \Delta p_e A_e) \qquad (16)$$

3. *Change of temperature in casing.* The axial elongation which would occur as a consequence of a temperature increase Δt of the casing after cementing would amount to $\lambda\, L\, \Delta t$.

λ = coefficient of thermal expansion.

The component of V required to balance this elongation amounts to:

$$V_3 = -E\lambda\Delta t\,(A_e - A_i) \qquad (17)$$

A temperature increase of the cemented casing increases the tendency to buckling.

4. *Method of landing.* The influences of slacking off or pulling up the casing (before landing) on the tendency to buckling can easily be taken into account by adding the adjustment of the weight indicator to the force V in equation (14). If the amount of slack-off in weight units is equal to S the component of V to be taken into account is:

$$V_4 = -S \qquad (18)$$

It should be observed that slacking-off the casing reduces the safety margin for buckling but improves the collapse resistance. The reverse is true for pulling up the casing.

5. *Drop of liquid level.* If there occurs a big drop (m) in liquid level inside the casing (see Fig. 2), it might be assumed

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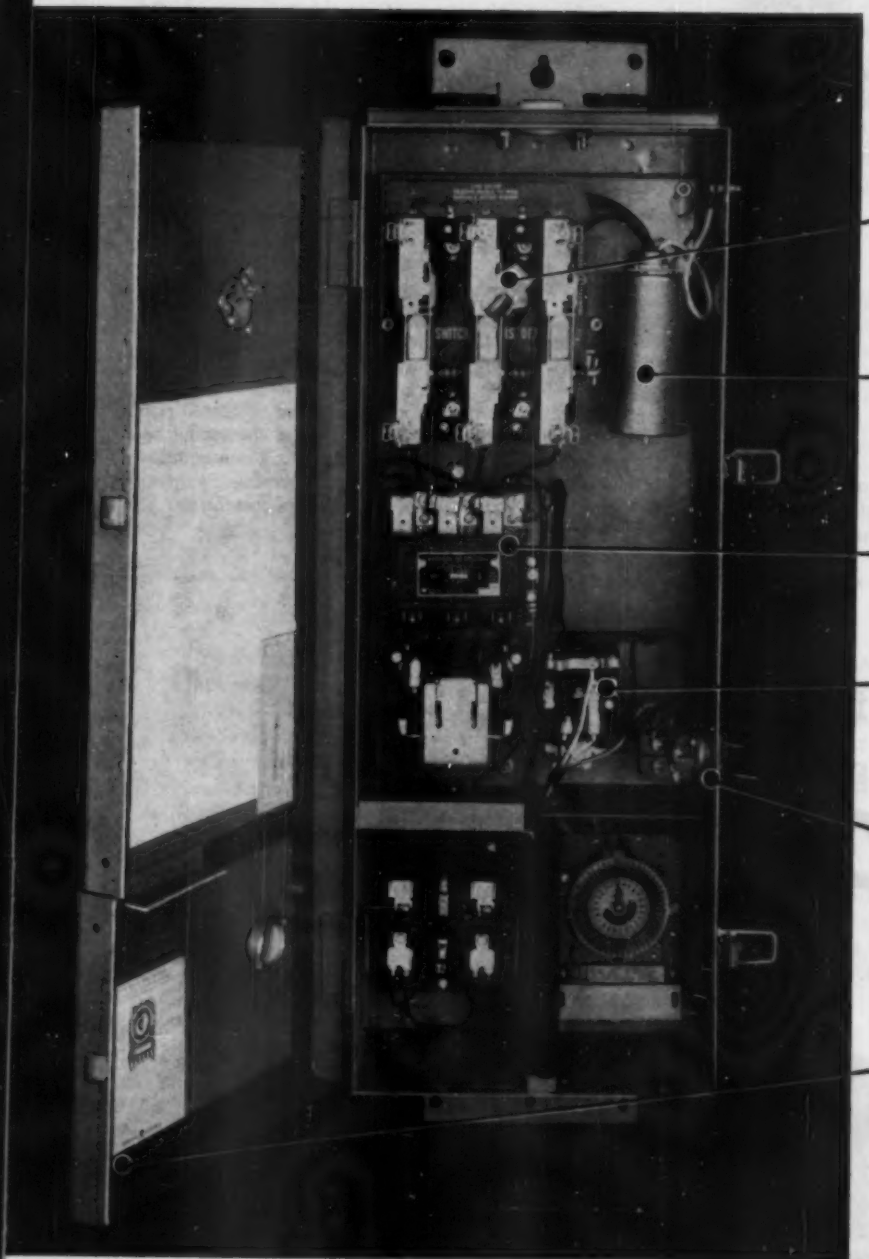

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that the whole casing is evacuated ($\Delta d_i = -d_i$). If the value of m is small, the correction can be approximated by taking $\Delta p_i = -m\, d_i$. Similar approximations can be made in the case of a liquid drop in the annulus. The approximations can always be made in such a way as to remain at the safe side.

In view of the inaccuracy of the general buckling criterion there is no justification in attempting to obtain any great accuracy in regard to these details.

6. *Combination strings.* In the case of a combination string where A_i may not be constant, it would be possible to apply corrections in the buckling criterion. For the same reason as mentioned in the previous paragraph, these corrections should preferably be omitted.

General Buckling Criterion for Cemented Casing

Various factors studied previously provide the general buckling criterion (B) for a cemented casing as follows:

$$B = h\,[d_s(A_e - A_i) + d_iA_i - d_eA_e] + l\,[d_s(A_e - A_i) + (d_i + \Delta d_i)\,A_i - (d_e + \Delta d_e)\,A_e] + L(\Delta d_eA_e - \Delta d_iA_i) + \Delta p_eA_e - \Delta p_iA_i + V > O \quad (14)$$

$$V = V_1 + V_2 + V_3 + V_4$$

$$V_1 = \mu L\,(\Delta d_iA_i - \Delta d_eA_e) \quad (15)$$

$$V_2 = 2\mu\,(\Delta p_iA_i - \Delta p_eA_e) \quad (16)$$

$$V_3 = -E\,\lambda\,\Delta t\,(A_e - A_i) \quad (17)$$

$$V_4 = -S \quad (18)$$

With the aid of this criterion, the tendency to buckling of a casing can be estimated for the conditions before as well as after cementing for any cross section between cement top and landing top.

The criterion shows that the tendency to buckling not only depends on changes of liquid densities after cementing but also on the liquid and cement slurry densities occurring before the cement has set.

In regard to top (gas) pressures, there is only an influence if changes occur after cementing.

A list of symbols used in the expressions (14) to (18) is given below.

- d_s = weight per unit volume of steel
- d_i = weight per unit volume of internal liquid
- d_e = weight per unit volume of external liquid
- d_c = weight per unit volume of cement slurry
- Δd_i = increase of internal liquid weight per unit volume, after cementing
- Δd_e = increase of external liquid weight per unit volume, after cementing
- Δp_i = increase of pressure on the liquid in the casing at its top, after cementing
- Δp_e = increase of pressure on the liquid around the casing at its top, after cementing
- r_i = internal radius of pipe
- r_e = external radius of pipe
- A_i = πr_i^2 = area of piping internal cross section
- A_e = πr_e^2 = area of piping external cross section
- h = depth of cemented part of casing
- L = distance between cement top and landing top
- l = length of piping from a certain cross section down to the cement top
- V = vertical reaction force exerted by the cemented portion of the casing on the free part of the casing between cement top and landing top as a consequence of changes of conditions after cementing
- Δt = temperature increase of casing after cementing
- S = amount of slack-off in weight units
- E = Young's modulus for steel

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μ = Poisson's ratio for steel
λ = Coefficient of thermal expansion for steel

Some Application of the Buckling Criterion

Example 1. It is first assumed that the weight per unit volume of the fluid outside the casing does not change after cementing ($\Delta d_e = 0$) and that the fluid inside the casing is replaced by low pressure gas, the weight and pressure of which are at first neglected. This means: $\Delta d_i = - d_i$

According to (15):

$$V_1 = - \mu d_i A_i L$$

With

$\mu = 0.3$:

$$V = V_1 = - 0.3\, d_i A_i L$$

It is further assumed that the depth of the cemented part of the casing is relatively small. ($h \approx 0$).

Taking the example of 7-in. 23-lb casing studied by Lubinski (3):

A_e = 38.47 sq in.
A_i = 31.81 sq in.
$A_e - A_i$ = 6.66 sq in.
d_s = 490 lb per cu ft
d_i = 18 lb per gallon = 134.3 lb per cu ft
d_e = 10 lb per gallon = 74.7 lb per cu ft

Substituting the values of Δd_i and V in equation (14) the criterion for the tendency to buckling (B_1) after the evaluation of the casing becomes:

$$B_1 = l[d_s(A_e - A_i) - d_e A_e] + L\, d_i A_i - 0.3\ L d_i A_i =$$
$$= l\,[d_s(A_e - A_i) - d_e A_e] + 0.7\ L\, d_i A_i.$$

Before evacuation of the casing, the buckling criterion (B_o) was:

$$B_o = l[d_s(A_e - A_i) + d_i A_i - d_e A_e] =$$
$$= \frac{l}{144}$$
$$(490 \times 6.66 + 134.3 \times 31.81 - 74.7 \times 38.47) = 324\, l$$

$$B_1 = \frac{l}{144}\,(490 \times 6.66 - 74{,}7 \times 38.47)$$
$$+ 0.7\,\frac{L}{144} 134.3 \times 31.81 = 2.7\, l + 20.8\, L$$

B_o and B_1 are expressed in lbs.

$$\frac{B_1}{B_o} = 0.083 + 0.64\,\frac{L}{l}$$

For the lower part of the casing ($l < 0.7$ L) the safety in regard to buckling has increased as a consequence of the evacuation. The reverse is true for the top part of the casing ($l > 0.7$ L).

Since B_o and B_1 are both positive, there is no tendency to buckling in either case.

It is further assumed that after the change described above a gas pressure $\Delta p_i = d_e L$ develops in the casing.

According to (14) and (16):

$$B_2 = B_1 - d_e L A_i + 0.6\ d_e L A_i = B_1 - 0.4\ d_e L A_i =$$
$$= 2.7\, l + 20.8\, L - 0.4 \times \frac{L}{144}$$
$$74.7 \times 31.81 = 2.7\, l + 14.2\, L$$

$$\frac{B_2}{B_o} = 0.083 + 0.44\,\frac{L}{l}$$

As compared with the original condition, it appears that the safety range in regard to buckling has increased for $l < 0.48$ L and has decreased for $l > 0.48$ L.

Example 2. For the casing mentioned in example 1, it is assumed that it is cemented under the condition:

$d_i = d_e$ = 10 lb per gallon = 74.7 lb per cu ft

It is again assumed that the depth of the cemented part of the casing is relatively small. After cementing and landing "as cemented", the drilling fluid is replaced by a mud with a weight per unit volume:

$d_i + \Delta d_i$ = 18 lb per gal = 134.3 lb per cu ft (drilling out of cement)

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Therefore, $\Delta d_i = 59.6$ lb per cu ft; $\Delta d_e = 0$.

Before the change of liquid in the casing, the buckling criterion (14) gives:

$$B_0 = \frac{6.66}{144}(490 - 74.7)\, l = 19.2\, l$$

After the change of liquid in the casing, the buckling criterion becomes:

$$B_1 = \frac{l}{144}(490 \times 6.66 + 134.3 \times 31.81 - 74.7 \times 38.47) - 59.6 \times \frac{31.81}{144} \times L + 0.3 \times 59.6 \times \frac{31.81}{144} \times L = 32.4\, l - 9.2\, L$$

B_1 will be negative for $l < 0.284$ L which means that the bottom part of the string will have a tendency to buckle.

Example 3. The influence of depth of the cemented part of the casing, considered in example 2, on the tendency to buckling should be investigated.

It is assumed that:

$h = 1500$ ft
$L = 4500$ ft
Total depth of well = 6000 ft.
$d_i = d_e = 74.7$ lb per cu ft
$\Delta d_i = 59.6$ lb per cu ft
$d_c = 16$ lb per gallon = 120 lb per cu ft
$d_s = 490$ lb per cu ft

Before the change of liquid in the casing, the buckling criterion (14) gives:

$$B_0 = \frac{1500}{144}(490 \times 6.66 + 74.7 \times 31.81 - 120 \times 38.47) + \frac{l}{144}(490 \times 6.66 + 74.7 \times 31.81 - 74.7 \times 38.47) = 1500 \times 7.1 + 19.2\, l = 10650 + 19.2\, l$$

After the change of liquid in the casing, the buckling criterion becomes:

$$B_1 = B_0 + 59.6 \times \frac{31.81}{144} l - 59.6 \times \frac{31.81}{144} L + 0.3 \times 59.6 \times \frac{31.81}{144} L =$$

$$= 10650 + 19.2l + 13.2\, l - 9.2\, L = 10650 + 32.4\, l - 9.2\, L$$

$$B_1 = 10650 + 32.4\, l - 9.2 \times 4500 = 32.4l - 30750$$

For various distances above the cement top, value of the buckling criterion B_1 will be as follows:

l (feet)	B_1 (lbs)
0	- 30750
500	- 14550
950	0
2000	34000
4500	115000

Under these conditions there will be a tendency to bottom buckling for values of l below 950 feet ($l < 0.21$ L).

This tendency to buckling could be avoided by applying a lower mud weight (e.g. 12 lb per gallon instead of 18 lb per gallon).

Example 4. The influence of a temperature rise and the method of landing a 7 in. 23 lb casing should be investigated.

It is assumed that:

$h = 1877$ ft
$L = 2600$ ft
Total depth of well: 4477 ft.
$d_i = d_e = 10.8$ lb per gal = 80.7 lb per cu ft
$d_c = 16$ lb per gal = 120 lb per cu ft
$d_s = 490$ lb per cu ft

If the casing were landed as cemented, the buckling criterion would be:

$$B = \frac{h}{144}(490 \times 6.66 + 80.7 \times 31.81 - 120 \times 38.47) + \frac{6.66}{144}(490 - 80.7)\, l = 8.43\, h + 18.93\, l = 18.93\, l + 15800$$

If no changes in conditions are expected after cementing, the allowable slack-off would be equal to 15,800 lbs.

If a 15° F rise in casing temperature is anticipated, the value of V_3 according to equation (17) would amount to:
$V_3 = -E \lambda \times 15 \times 6.66 = -200 \times 15 \times 6.66 = -20{,}000$ lbs
In this case, any slack-off of the casing string could induce buckling of the lower part of the casing and should, therefore, be avoided. A small amount of pulling up the casing might even be considered desirable in this case.

Acknowledgment

The author is very much indebted to Prof. Dr. J. J. Koch (Delft University), Mr. H. M. Boers (N. V. De Bataafsche Petroleum Maatschappij, The Hague), and Mr. W. R. Cox (Shell Oil Company, Corpus Christi) for their offering valuable suggestions and criticism during the preparation of this paper.

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* * *

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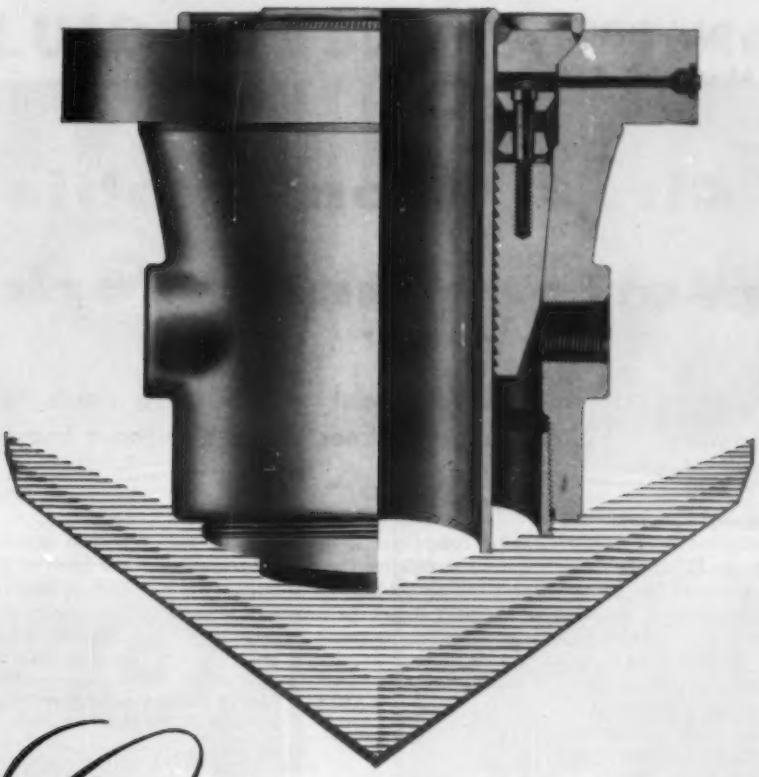

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Lost Circulation Problems in Completions and Workovers

Loss of clean-out and treating fluids to permeable and fractured oil zones stopped without impairing productivity

G. M. Purswell
Cherokee Laboratories, Incorporated
Casper, Wyoming

IN well completions and work-overs, experience in the Rocky Mountain area has shown that a temporary lost circulation material composed of walnut shells and oil soluble resin effectively prevents the loss of clean-out and treating fluids to permeable oil bearing zones without impairing productivity.

This material has made circulation possible through fractured zones in the Rangely field where previous efforts to clean out wells had failed. Multiple fracturing and acidizing operations have also been performed using small quantities of the plugging agent between stages.

Description of material. A temporary plugging material, known as "Tem-Plug" is composed of 75 per cent by weight oil soluble petroleum derived resin and 25 per cent by weight ground walnut shell. The resin is ground finer than 4 mesh and the shells are ground so as to pass an 8 mesh screen and be retained on a 16 mesh screen. Function of the walnut shell is to form a high strength bridge across the zone of loss while the function of the resin is to filter out on the bridge and thereby complete the seal.

Physical characteristics of the material are shown on Table 1.

TABLE 1: Physical Characteristics

	Walnut Shells	Resin
1. Form	Granular solid	Granular solid
2. Percentage by weight	25	75
3. Specific gravity	1.25—1.40	1.1
4. Sieve analysis	—8+16	—
5. Melting point	None	293 F
6. Compaction in storage	None	None
7. Solubility	Insoluble in water, acid and oil	Soluble in kerosine and most crude oils. Insoluble in water and acid.

Solubility rate of the resin is affected primarily by temperature and aromatic content of the crude oil. Average dissolution time is 5 to 10 hours when added to a circulating crude oil. Under static conditions, 2 to 4 days are required to dissolve the packed resinous seal and permit passage of fluid.

Table 2 shows the results of laboratory tests on the rate of dissolution of the resin.

TABLE 2: Rate of Dissolution of Petroleum Derived Granular Resin in Crude Oils

Origin of crude oil	Est. avg. bottom-hole circulating temp. (deg F) of field	Concentration of resin (lb/bbl)	Percentage dissolved after 1 hr	7 hr	24 hr	72 hr
Andector field, Tex.	100	10	5	62	95	100
Rangely field, Colo.	102	10	19	44	97	100
Slaughter field, Tex.	98	10	30	88	100	—
Midland Farms field, Tex.	110	10	28	90	100	—
Pembina, Canada	105	10	12	51	93	100
Foster field, Tex.	90	10	15	82	97	100
South Cowden field, Tex.	90	10	0	19	100	—
Sholem Alechem field, Okla.	105	10	0	0	11	85
Panhandle field, Tex.	86	10	0	0	32	100
East Velma field, Okla.	90	10	0	1	44	100
Jameson Strawn field, Tex.	102	10	16	—	94	100

After the resin is dissolved, the walnut shell may remain, wholly or in part, in the loss zone, but because of their particle size wil lnot affect productivity.

The results of laboratory tests on sealing characteristics are shown in Fig. 1. These results were obtained by slot sealing tests. A bentonite solution was used as a carrying fluid. All seals were subjected to 1000 psi differential pressure.

Field application. Individual well conditions determine the quantity to be used. Generally, a concentration of 10 to 50 lb per bbl is added to 10 to 50 bbl of the carrying fluid. The mixture is then injected into the well bore in the form of a "pill." Squeeze pressure may or may not be desirable after circulation is restored. In case a lost circulation zone of considerable thickness is encountered, it is advisable to add 5 to 20 lb per barrel to the entire system. When adding the material to low specific gravity carrying mediums such as crude oil, the carrying medium should be agitated to prevent settling.

This temporary lost circulation material has been successfully employed in several fields in the Rocky Mountains. It has been used in drilling and completion programs, hydraulic fracturing and acidizing operations and in remedial measures where fluid is lost to the producing zone.

Widest use has been in the Rangely field of northwest Colorado. The Rangely field was drilled during the early 1940's. Completion practice at

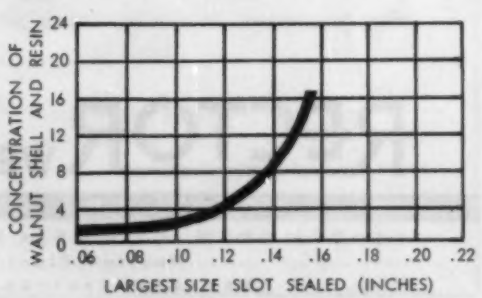
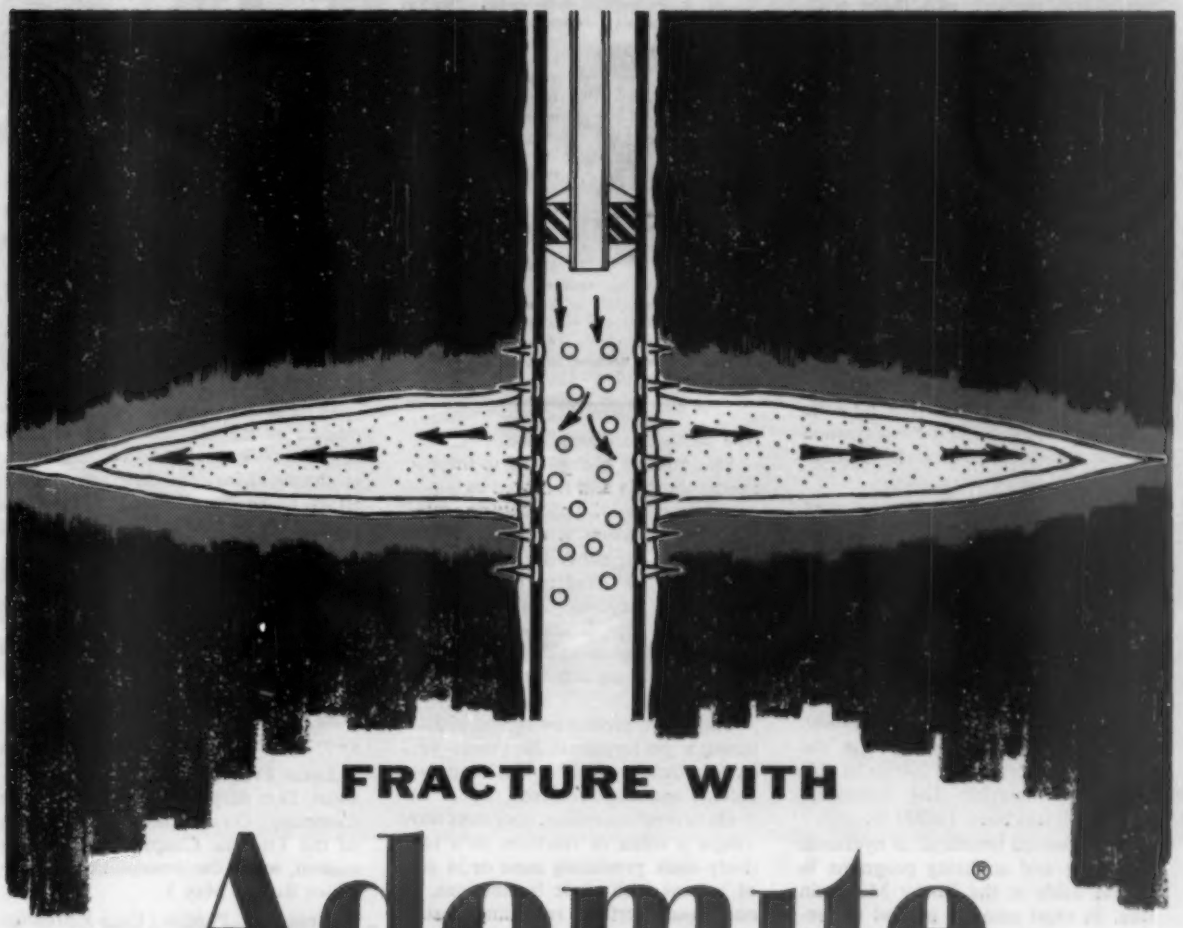


FIG. 1. **Sealing characteristics** of oil-soluble temporary plugging agent.

CUT FLUID LOSS TO A MINIMUM



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the time was to set pipe on top of the Weber sand (approximately 600 ft thick), drill through and shoot with explosives. Majority of the wells were never cleaned out to the original depth after being shot. Decline in production has made it necessary to clean these wells out to bottom and recomplete.

A reverse circulation procedure is used to clean the wells to their original depth, and Rangely crude oil is used as a circulating fluid. Lost circulation is a serious problem during the clean-out operation. One well is reported to have lost a total of 30,000 bbl of crude oil in several unsuccessful attempts to clean it out to bottom. The successful work-over of this well was finally accomplished by using oil-soluble material and, to date approximately 60 wells in the Rangely field have been cleaned out and fractured successfully by controlling the loss of circulation.

A sand oil fracturing process is used after the clean-out. A flow back of sand after the fracturing process necessitates a second-clean-out job. A "pill" type injection is added to the circulating system through a lubricator tied directly to the flow line into the well head. A concentration of 10 to 20 lb per bbl in 20 to 30 bbl of crude oil is injected in event of any lost circulation.

The average work-over job in the Rangely field requires 1500 lb of this circulation material. The maximum on one job has been 10,000 lb.

It has proved beneficial in hydraulic fracturing and acidizing programs in several fields in the Rocky Mountain area. In most cases, it is used to produce a secondary fracture system in addition to a system in existence. Concentration of 15 to 25 lb per bbl are added to gelled hydrocarbon or gelled acid. The volume required is slightly greater than the volume of the open hole below the casing shoe.

This mixture is displaced to the bottom of the hole and followed by a predetermined quantity of fracturing fluid. When the mixture is on bottom, the well is shut in, either by a packer arrangement or Braden head valves. Pressure is applied slowly until the existing fracture is sealed. Then normal fracturing or acidizing and sand oil procedures are followed to complete the operation.

The above procedure can be applied through perforations; however, very close control must be maintained over volume and displacements.

On several occasions, operators have sought a series of fractures in a relatively thick producing zone or in case of a zone with shale laminations. In one case, surface recording instruments indicated that five successive fractures were produced in one continuous pumping operation.

Fig. 2 shows a typical pressure curve obtained in a multiple fracture operation. * * *

The Author

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He worked for several independent drilling contractors in Wyoming, Louisiana, Oklahoma and New Mexico before joining Magcobar in 1948 as a mud engineer. He became associated with Cherokee in 1954.

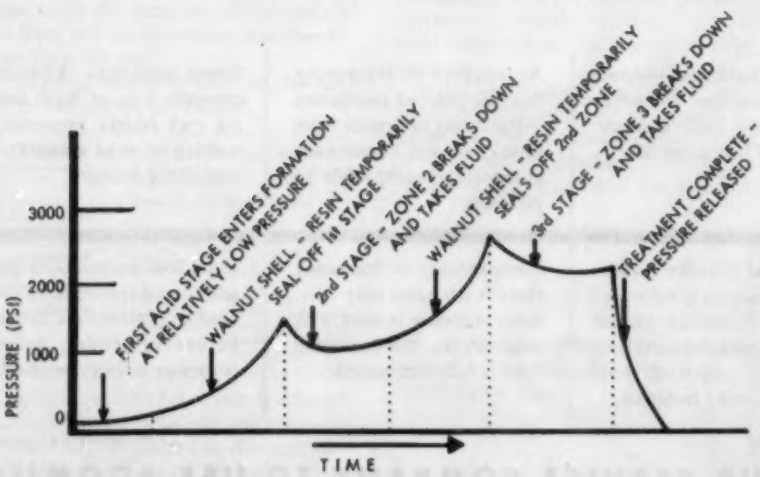

PRESSURE (PSI)
3000
2000
1000
0
TIME
FIRST ACID STAGE ENTERS FORMATION AT RELATIVELY LOW PRESSURE
WALNUT SHELL - RESIN TEMPORARILY SEAL OFF 1st STAGE
2nd STAGE - ZONE 2 BREAKS DOWN AND TAKES FLUID
WALNUT SHELL - RESIN TEMPORARILY SEALS OFF 2nd ZONE
3rd STAGE - ZONE 3 BREAKS DOWN AND TAKES FLUID
TREATMENT COMPLETE - PRESSURE RELEASED

FIG. 2. **Pressure curve** during typical multiple fracturing or acidizing operations.

Five PE Educators Receive AAODC Honorariums

Five educators from accredited schools of engineering this month have been saluted by the American Association of Oilwell Drilling Contractors for their work in developing and training young engineers for the drilling industry.

The 1956 Honorariums went to: Professor Paul Roston, Missouri School of Mines and Metallurgy; C. Drew Stahl, The Pennsylvania State University; Professor C. V. Kirkpatrick, The University of Houston; C. E. Murphy, The Texas College of Arts and Industries; and Professor Frank G. Miller, Stanford University.

In campus ceremonies, directors and officers of the AAODC presented the Association's checks and award plaques to the recipients for their outstanding efforts to perpetuate the idea of drilling careers.

The Honorariums, established in 1953, have gone to professors in 16 of the 19 accredited schools of petroleum engineering in the nation. "This is our way of expressing appreciation to petroleum engineering professors for their interest in our industry," says E. Dale Mount (Harry Bass Drilling Company, Dallas), AAODC president.

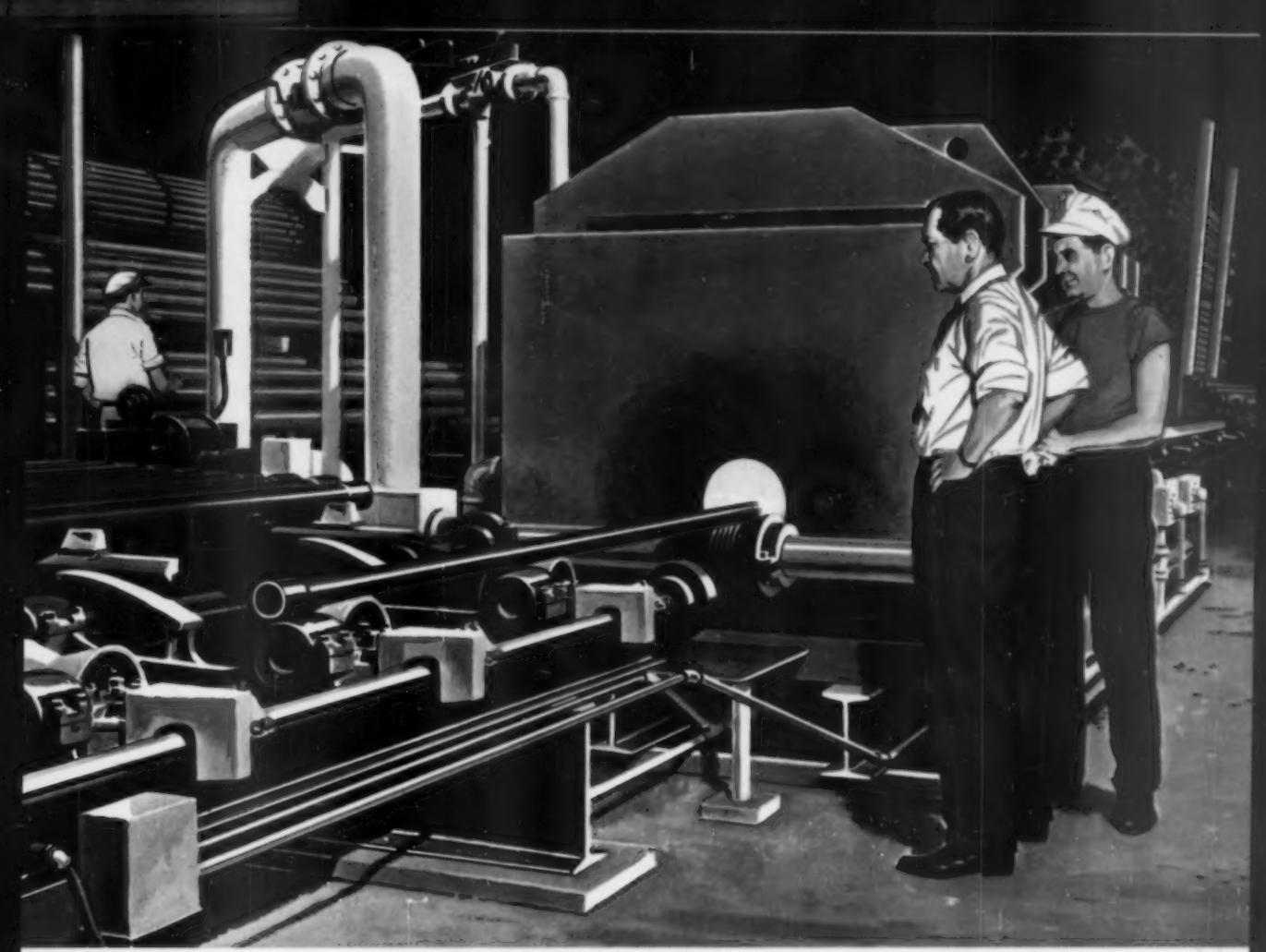
Local Presentations. In Rolla, Missouri, Don Slape (Don Slape Drilling Company, Olney, Illinois), chairman of the Tri-State Chapter of the Association, made the presentation to Professor Roston May 3.

George H. Pappas (Paco Petroleum Corp., Mt. Carmel, Illinois), a vice-president of the AAODC, honored Stahl at Penn State following a discussion of the need for drilling engineers by H. J. Magner, district manager of Delta Gulf Drilling Company. The presentation took place May 15.

On May 22, C. F. Whaley (Chet Whaley Well Servicing Co., Inc., Houston) awarded the plaque to Professor Kirkpatrick at the University of Houston.

Murphy received his salute from Earle C. Hellums (Gracey-Hellums Corporation, Houston), the AAODC vice-president for the Gulf Coast Region. A delegation from the Association's Corpus Christi Chapter headed by Chapter Chairman R. W. Yarborough Drilling Company, Corpus Christi) was on hand May 30 to acknowledge Murphy's contributions to the industry.

Professor Miller's Honorarium was presented on May 21 by J. K. Kellogg (K. L. Kellogg & Sons, Compton, California), a director of the Association, at afternoon ceremonies.



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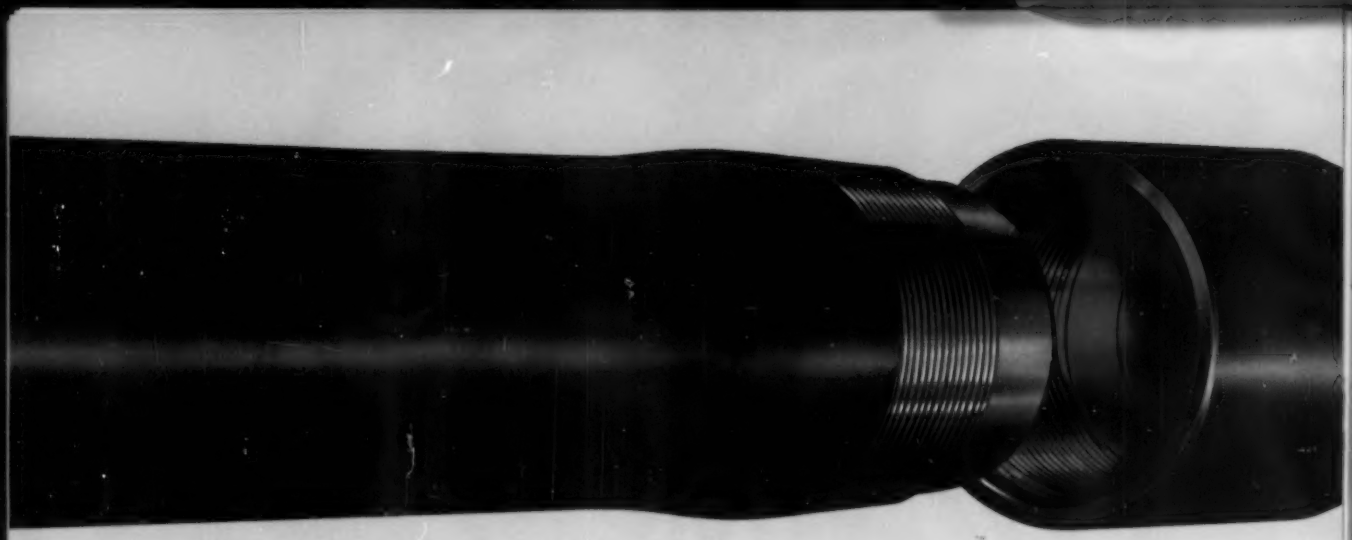

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After carefully-controlled shot-blasting and cleaning operations, a tough epoxy-phenolic internal surface coating is applied by alternate spraying and baking. A uniform thickness of not less than .005 inches is the result. Ask the National representative in your area about this service—and any other details you'd like to have about SPANG Tubing.

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Particularly useful for producing deep wells and high pressure wells, this quality tubing—

Provides maximum running speed; fast joint make-up
Has 100% joint strength
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Has 50% less connections
Provides positive shoulder contact engagement
Has a streamlined exterior
Is available in grades J-55, N-80 and P-105 to suit every well condition

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Field tests have proved that you'll minimize a host of common tubing troubles when you use Spangseal. This integral joint tubing—
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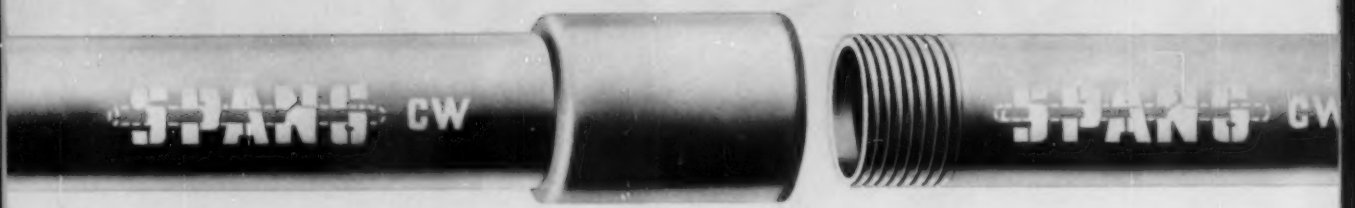

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In countless oilfield applications, SPANG CW has consistently proved itself for dependable general service work. That's because it's made under close quality control conditions—like all the other famous SPANG oil field tubular products. The manufacturing care behind SPANG CW makes it easy to work with and install. Thorough tests and inspections before shipping insure its top strength and long service life—features that pay off wherever you put it to work.

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Theoretical Analysis and Field Data Show . . .

Down-Hole Chambers Increase Gas-Lift Efficiency . . . . . Part 1 of 2 Parts

Permits depletion of low bottom-hole pressure wells; cuts lifting costs on stripper wells; maximum fluid recovery with minimum fluid head; reduction in gas-fluid ratios

H. W. Winkler and **George F. Camp**
Camco, Incorporated, Houston, Texas — *Rainbo Sales, Inc., Oklahoma City, Okla.*

ACCUMULATION chambers provide an inexpensive, trouble-free type of lift which will enable the operator to produce low bottom-hole pressure stripper type wells to depletion. In shallow wells, the gas lift equipment for a chamber installation with one conventional valve will not exceed $500.00, including the surface controller. If the operator has a few joints of 3 or 4-in. diameter line pipe and a hookwall packer, the additional costs to install the gas lift equipment will be primarily pulling unit charges.

A chamber generally is applied to high productivity, low bottom-hole pressure and low productivity, low bottom-hole pressure wells. In either type well, the producing bottom-hole pressure is not sufficient to support a column of fluid that can be efficiently intermitted as a solid slug by the conventional intermittent installation. The chamber provides increased slug volumes per linear foot of head above the formation. This means more fluid per cycle and is particularly advantageous in wells which must be operated at maximum cycle rates.

For a well with 5½-in. OD — 17 lb casing and 2-in. tubing, ratio of the annular volume between the chamber and dip tube to the tubing above the chamber, as shown in Fig. 1, is 4.6 to one. One foot of fluid in the chamber annulus is equal in volume to 4.6 ft of fluid in the tubing. A 200-ft fluid head build-up in the dip tube and chamber annulus would represent 920 ft plus 200 ft or 1120 ft of fluid head in the dip tube and tubing with the chamber

Presented under the original title "Increasing Production by Gas Lift With Chambers" at the Third Annual West Texas Short Course on Oil Lifting, sponsored by Texas Technological College, April 19-20, 1956, at Lubbock, Texas.

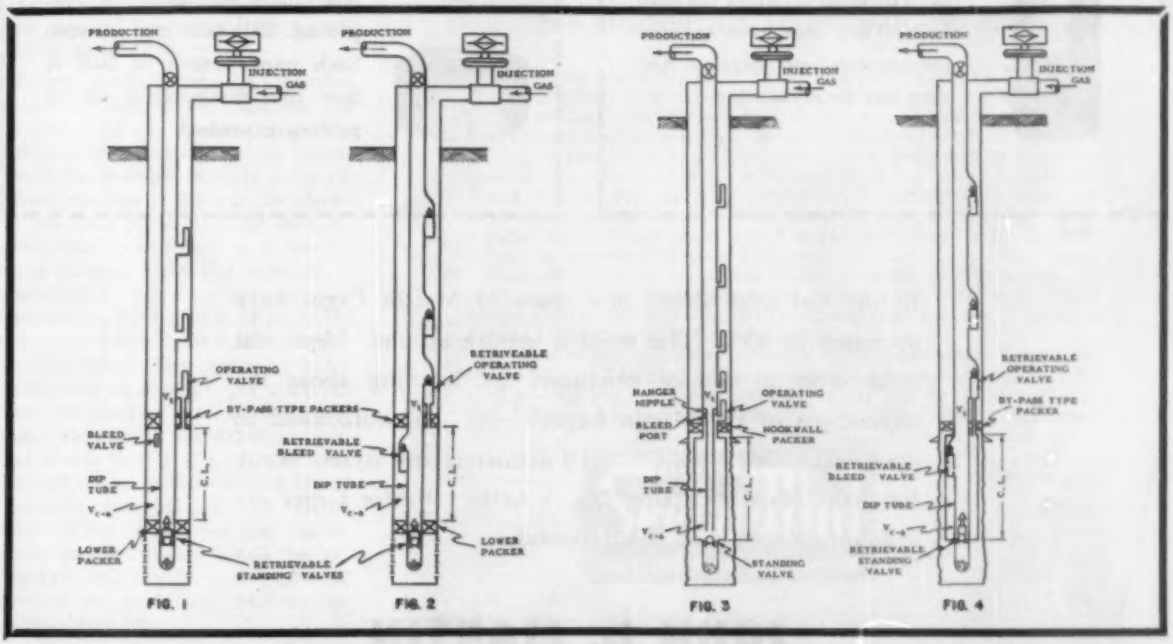

FIG. 1. Two-packer chamber installation with conventional flow valves and retrievable standing valve.
FIG. 2. Two-packer chamber installation with retrievable flow valves, bleed valve and standing valve.

FIG. 3. Insert chamber installation with conventional valves using hanger nipple and hookwall packer.
FIG. 4. Insert Chamber installation with retrievable flow valves, bleed valve, and standing valve.

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Ball & Seat life is usually doubled, on the average. With the rubber guides, there is much less chattering, chipping and pitting. Ball falls true on seat. Such improvement in Ball & Seat life eliminates a lot of pulling expense.

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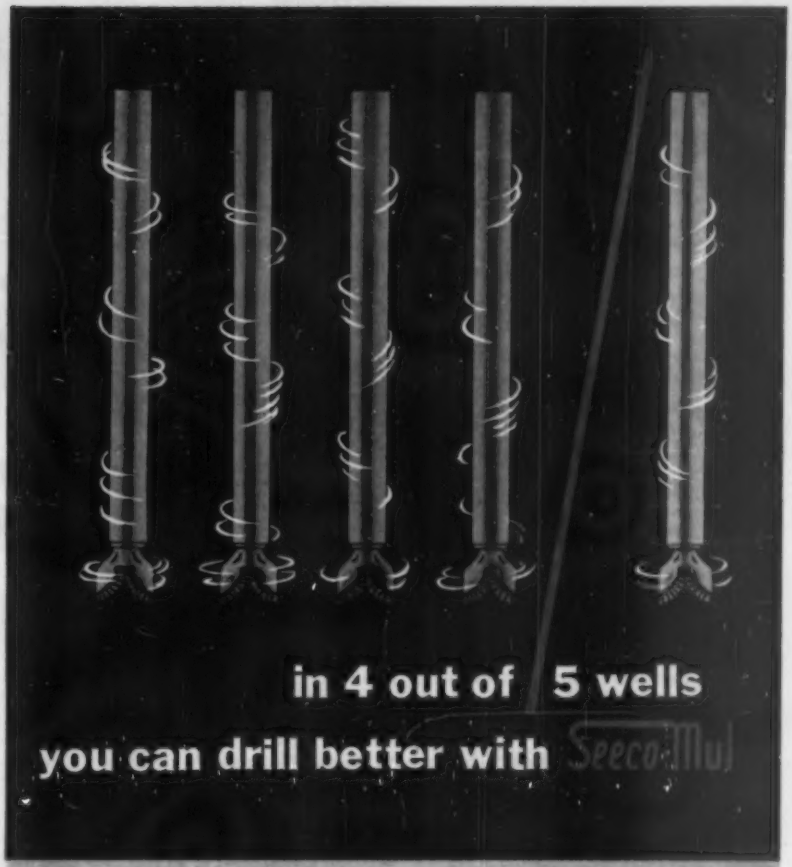
annulus displaced by gas. The 200 ft represents fluid already in the dip tube before the chamber is emptied.

Injection point lowered. A chamber provides a method of dropping the point of gas injection near total depth in wells with several hundred feet of perforations or open hole. The lower point of gas injection creates a greater drawdown, thus resulting in a lower producing bottom-hole pressure. This will increase production in most wells. For a given head of fluid against the formation, the chamber permits a much greater fluid recovery per injection cycle than does any other gas lift method. The actual point of gas injection is at the lower end of the dip tube. Since the end of the dip tube is usually only inches above the bottom of the chamber, the bottom of the chamber is generally considered the point of gas injection for most chamber length calculations.

Injection gas enters the chamber on top of the fluid in all installations discussed. Before gas can enter the tubing, all fluid must be displaced from the chamber. Fluid is moving at an optimum velocity before the injection gas enters the tubing; therefore, breakthrough of the lift gas is held to a minimum. Chamber design offers the efficiency of a plunger with the advantage of being able to produce considerably more fluids per day from a high productivity, low bottom-hole pressure well. A greater number of gas injection cycles per day are possible with a chamber than with a plunger because of the time required for the plunger to fall back to its bottom-hole stop.

Lower gas-fluid ratio. A chamber should be used if the injection gas pressure is greater than the producing bottom-hole pressure. The only limitation to the chamber capacity is the resultant injection pressure in the chamber less back pressure. Large fluid recovery per cycle results in a low injected gas-fluid ratio. For example: a conventional intermittent installation is producing 0.5 bbl of fluid per cycle with a 300 ft fluid head build-up opposite the valve. The operating valve passes 2000 cu ft of gas per cycle between its opening and closing pressures; therefore, the injection gas-fluid ratio is 4000:1. If a chamber were installed in this well whereby 2 bbl of fluid were recovered per cycle for the same volume of injection gas, the injected gas-fluid ratio would be reduced to 1000:1 by increasing the fluid recovery per cycle and reducing the gas breakthrough.

Up-hole chambers. Lifting efficiency of many present intermittent gas lift installations with low productivity indices and high bottom-hole pressures can



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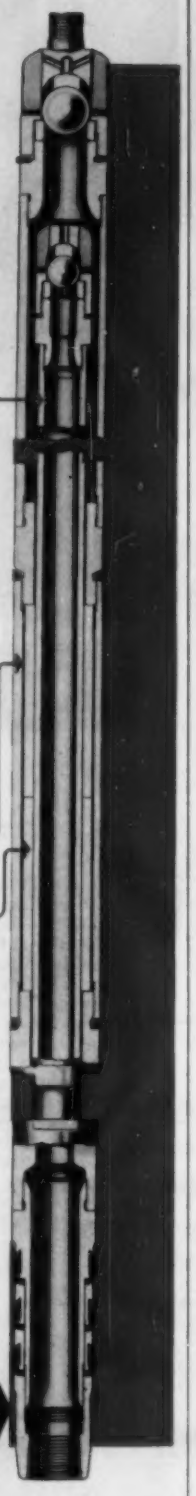
In well after well, oil operators report highly successful pumping with Pacific "Oil States," particularly after trying cup and ring pumps or metal-to-metal pumps with wide tolerances between plungers and tubes. The Pacific "Oil States" offers a new approach to pumping sandy or dirty oil wells. Specifically manufactured to a very close tolerance between plunger and liners, so as to eliminate sand passing between the sealing surfaces which normally cut and score plunger and liners. The Pacific "Oil States" is not merely a "clean-out" pump. It is engineered to pump sand with its "surging action" and further, to pump with a high efficiency made possible only by the close tolerance.



Check these features:

- Furnished with a tolerance between plunger and liners in fits as close as Minus ½ thousandth...
- Furnished in standard steel with stress-proof, heat treated fittings for normal sandy pumping...
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- Furnished in pump lengths from 4 feet to 20 feet, with a wide choice of arrangements of valves and fittings...
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be improved with up-hole chambers. A solid fluid slug with minimum fall-back is assured by a chamber because injection gas does not enter the tubing until fluid is moving rapidly toward the wellhead. A chamber will increase daily production by permitting an overall lower average producing bottom-hole pressure. It provides maximum slug volume for minimum head against the formation. A plot of formation pressure build-up versus time reveals that a well has a maximum rate of pressure build-up immediately after shut-in. The increase in bottom-hole pressure after shut-in is a function of reservoir fluid feed-in. By properly locating an up-hole chamber, the well can be produced in the rapid build-up portion of the curve, thus increasing production by increasing the feed-in. These up-hole chambers are ideally suited to low productivity, high bottom-hole pressure wells which must be gas lifted against high wellhead tubing back pressures.

Chambers vs conventional design. An example comparing chamber versus conventional gas lift design illustrates the theoretical chamber advantages in terms of drawdown and barrels of fluid per day. A complete list of all the symbols and abbreviations with their definitions and units are included in this paper.

Well Data: Total depth = 10,000 ft. 5½-in. OD 17 lb casing; 2-in. tubing. Productivity index = 0.05 bbl/day/psi. Static fluid gradient = 0.4 psi/ft. Tubing back pressure at wellhead = 200 psig. Shut-in bottom-hole pressure = 1757 psig. Assumed intermitting rate = 1 cycle/hour.

Solution: Step 1: Determine maximum possible production in barrels per hour.

(a) Minimum bottom-hole pressure would be tubing back pressure plus the gas column weight.
$P_m = P_w + dP$
$P_m = 200$ psig + 50 psi = 250 psig

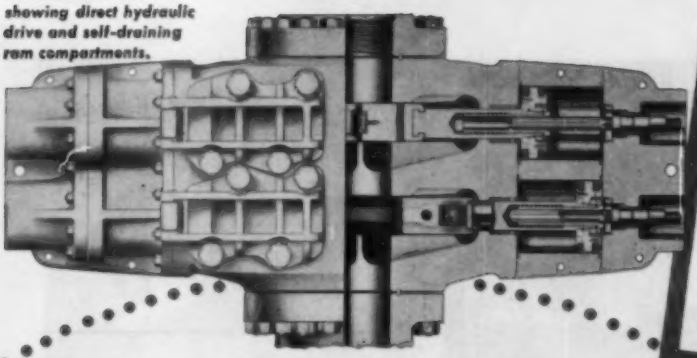
(b) Maximum possible production per day
$Q_o = P.I. (P_s - P_m)$
$Q_o = 0.05 (1757 - 250) =$ 75.35 BOPD
Therefore, maximum hourly production $Q_o/24 = 3.14$ BOPH

Step 2: Determine average flowing bottom-hole pressure with conventional gas lift design.

(a) $V_t = 3.87$ bbl/1000 ft (for 2-in. tubing)

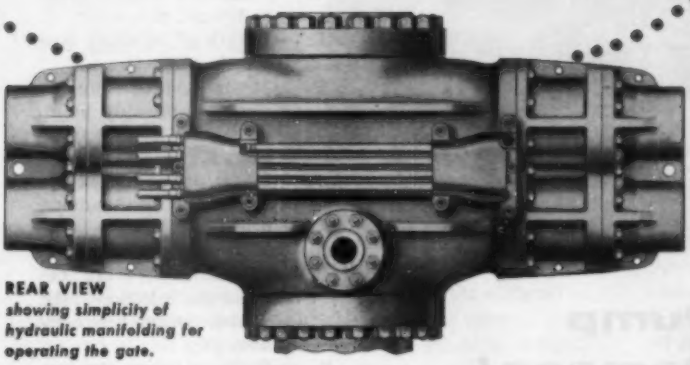
(b) Hourly feed-in 2-in. tubing $= \frac{3.14 \text{ BOPH}}{V_t} = 811$ ft/hr

CUTAWAY VIEW
showing direct hydraulic drive and self-draining ram compartments.



Feature by Feature

they all add up to SHAFFER!



REAR VIEW
showing simplicity of hydraulic manifolding for operating the gate.

What do *you* value most in cellar control gate equipment? . . . Compactness? . . . Convenience? . . . Simplicity? . . . Safety? . . . Versatility? In Shaffer Hydraulic Cellar Control Gates you get all these—and more—to a degree unsurpassed by any other equipment. Compare—point by point, feature by feature—the *extra* values you get in Shaffer equipment, and you'll know why they are the choice of so many leading operators . . .

FIELD-PROVEN DEPENDABILITY

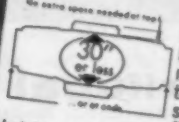
is probably the most important feature to look for in any pressure-protection equipment, and in Shaffer Hydraulic Gates you get safety backed by the organization that pioneered cellar control gates more than three decades ago. Successful from the first gate built, Shaffer Gates have nevertheless gone through a constant program of development to always keep ahead of the industry—and are today accepted as standard throughout the oil world.

SIDE DOOR RAM CHANGES

With Shaffer Hydraulic Gates there's no need to dismantle the gate each time the rams are changed. You simply open two doors in the side of the body, slide out the ram assembly, change rams, replace the assembly and bolt the doors shut. Closing the doors automatically aligns the rams within the body.

There's no need to allow extra room above the gate or at the ends to change rams—and complete ram changes can be made whether the pipe is in or out of the hole!

THREE-WAY COMPACTNESS



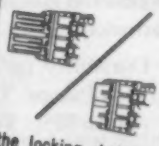
Space saved in the cellar is particularly valuable space. It means lower rig-up costs, smaller cellar requirements, simpler connections . . . and you save important space with Shaffer Hydraulic Gates. In all three dimensions—height, width and length—Shaffer Hydraulic Gates are unusually compact!

Even in sizes as large as 13⅝" (12" Series 900) Single Gates require only 18½" total height—Double Gates (two compartments in one body) only 30". There's no need for extra room above the Gates—nor need the compact length dimensions be expanded endwise—to permit ram changes.

SELF-DRAINING COMPARTMENTS

No detrimental sand or mud accumulations can interfere with free ram travel when you use Shaffer Gates. Note how the rams travel on high guide ribs above the steeply-sloped gate bottoms which quickly drain mud and sand back into the well. Also, since well pressure is free to flow to the back of the rams, it actually assists in the closing and sealing action.

RISING or NON-RISING SHAFTS



Whether you prefer the extra compactness of a non-rising shaft or the quick indication of ram position afforded by a rising shaft—you get the design you prefer from Shaffer. In both designs, built-in body extensions protect the locking shafts against damage in all positions—extended or retracted!

Get the full story

on these and many other Shaffer advantages before you invest in any pressure control equipment. And for those who prefer mechanical operation, Shaffer also provides a complete line of Double and Single Mechanical Cellar Control Gates with rams that are interchangeable, size for size, with those in Hydraulic Gates. This saves on inventory, simplifies maintenance where both types are used. See your nearest Shaffer representative for complete details—or write direct.

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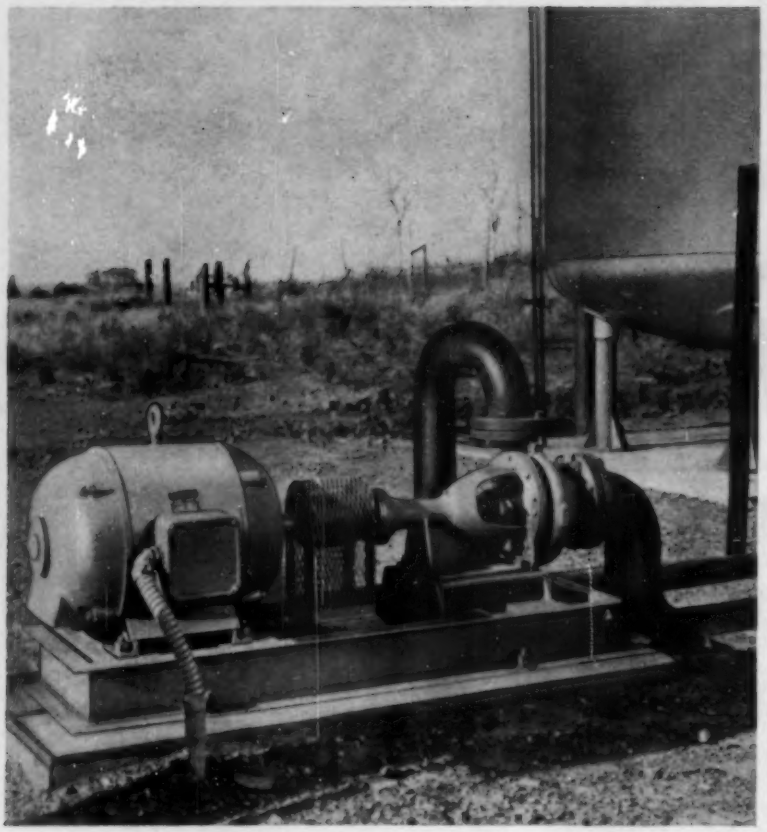
(c) Effective pressure build-up per cycle
$(P_f - P_m) = 811$ ft/hr (S.G.) $= 324$ psi

(d) Average flowing bottom hole pressure $=$
$P_m + \frac{P_f - P_m}{2} = 250 + \frac{324}{2} = 412$ psig

Definition of Symbols

C.L. —Chamber length, ft.
dP — Gas column weight, psi.
D.T.L. — Dip tube length, ft.
F.L.B. — Maximum producing fluid level above bottom of chamber, ft.
F.L.T. —Maximum producing fluid level above top of chamber, ft.
H — Maximum head $= (P_f - P_w)/S.G.$, ft.
O.S.L. — Length of oil string used for chamber, ft.
P_f — Maximum producing bottom-hole pressure build-up between gas injections, psig.
P_i — Injection gas pressure available inside chamber, psig.
P_m — Minimum producing bottom-hole pressure between gas injections, psig.
P_s — Shut-in bottom-hole pressure, psig.
P_w — Wellhead tubing pressure, psig.
P.I. — Productivity Index, bbl/day/psi.
Q_o — Daily oil production, bbl/day.
R — Ratio of annular volume of chamber to volume of tubing V_{c-a}/V_t, no units.
R_L — Ratio of annular volume of liner to volume of tubing V_{L-a}/V_t, no units.
R_{t-a} — Ratio of annular volume of tubing to volume of tubing V_{t-a}/V_t, no units.
S.G. — Static gradient of produced fluid, psi/ft.
V_{c-a} — Annular volume between dip tube and chamber, bbl/1000 ft.
V_{d-t} — Volume of dip tube, bbl/1000 ft.
V_{L-a} — Annular volume between dip tube and liner, bbl/1000 ft.
V_t — Volume of tubing above chamber, bbl/1000 ft.
V_{t-a} — Annular volume between dip tube and tubing, bbl/1000 ft.



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*Typical rig floor scene after 1½ years use of BLACK MAGIC in OHIO'S record breaking Paloma well.

*Typical rig floor scene of a well using water base mud.

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Over 10,000 BLACK MAGIC jobs have proved it pays big round dollars to the operator who insists on the right oil base drilling mud. Get all the facts and case histories. Try BLACK MAGIC early in your drilling program so you'll benefit from higher initial production and greater ultimate recovery from more wells. Write for literature to Oil Base, Inc., 130 Oris Street, Compton, California.

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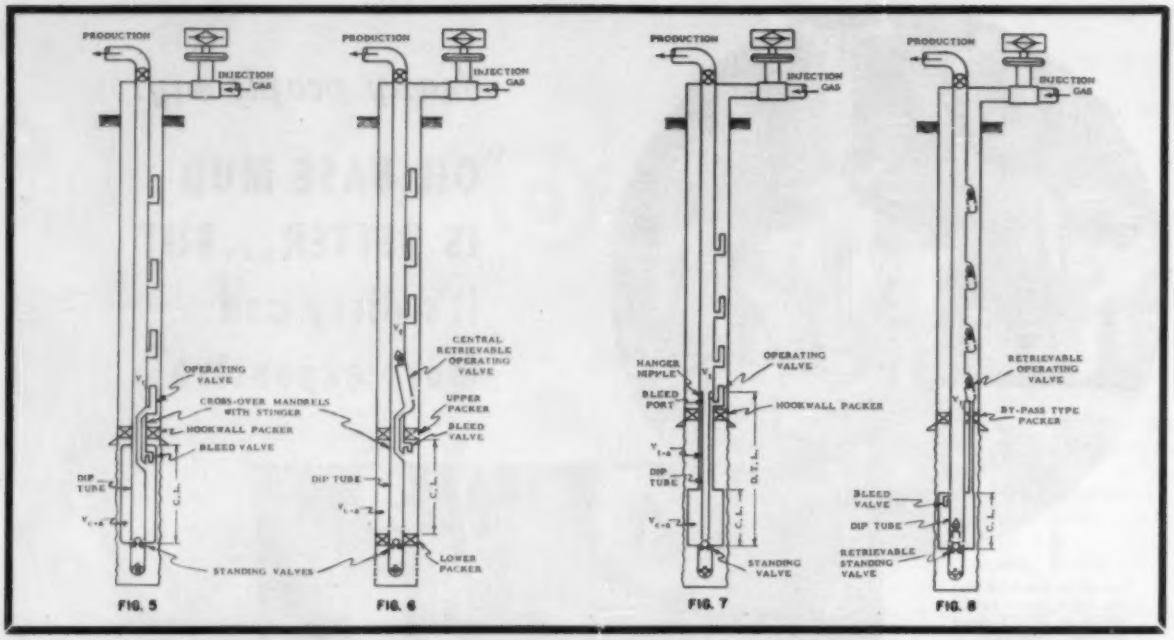

FIGS. 5 and 6. **Chamber installations** with cross-over mandrel replacing by-pass type packer. Central retrievable valve offers maximum flexibility with minimum investment.

FIG. 7. **Insert chamber** installation with packer located several hundred feet above chamber. Conventional valves and hanger nipple are used.

FIG. 8. **Insert chamber** with retrievable flow valves and standing valve in installation where packer is located several hundred feet above chamber.

Step 3: Determine average flowing bottom-hole pressure with chamber.

(a) Determine chamber length assuming chamber full with 3.14 bbl feed-in for a two-packer chamber with 2-in. dip tube.
$V_{c\text{-}a}$ (C.L.) + $V_{d\text{-}t}$ (C-L) = 3.14 bbl
17.8 bbl/1000 ft (C.L.) + 3.87 bbl/1000 (C.L.) = 3.14 bbl
C.L. = 3.14 ÷ 21.67 bbl/1000 ft = 145 ft

(b) Effective hourly pressure build-up = C.L. (S.G.)
= 145 ft (0.4 psi/ft) = 58 psi
= $P_f - P_m$

(c) Average flowing bottom hole pressure =

$$P_m + \frac{P_f - P_m}{2} = 250 + \frac{58}{2} = 279 \text{ psig}$$

Step 4: Subtract Step 3 from Step 2 to compute chamber advantage in terms of drawdown.
Additional drawdown with chamber = 412 psig — 279 psig = 133 psi

Step 5: Determine chamber advantage in terms of barrels of oil per day.
Q_o = Drawdown (P.I.)
Q_o = 133 (0.05) = 6.65 BOPD advantage

In the above example, the P.I. curve is assumed to be a straight line function. Although the well's P.I. is actually reduced as bottom-hole pressure declines, the problem does illustrate that lower operating bottom-hole pressures can be attained with a chamber. This means more production.

Types of Chambers and Their Design

A chamber design is an adaptation of the close intermittent installation. For successful operation all chamber installations must have an operating valve, standing valve and bleed port which function properly. There are two basic types of chambers: (1) insert or bottle type, and (2) two-packer type.

The insert chamber generally employs only one packer. Either of these basic types can be modified in many ways for application to individual well conditions. These modifications depend primarily on the length, size, and condition of the open hole or perforated interval, condition of the casing, injection pressure, producing bottom-hole pressure, producing gas-fluid ratio; and any unusual well conditions such as sand, salting, etc. Chamber designs are divided into the following classifications:

1. Conventional chamber installation.
2. Insert chamber installation with packer several hundred feet above chamber.
3. Two-packer chamber installation with upper packer in casing and lower packer in liner.
4. Chamber installation with dip tube larger than tubing.

Chamber lengths are calculated and checked for each classification. These simplified volume calculations based on maximum head for checking the proposed chamber length are recommended to assure a chamber design that will function properly. Symbols and abbreviations with their defiitions and units are shown on preceding page.

Conventional chamber installation. This can be either an insert or a two-packer type. Variations of conventional chamber installations are shown in Fig. 1 through 6. If the working fluid level does not exceed the top of the chamber and the dip tube and chamber lengths are the same, the generally accepted chamber formula can be used as shown in Example 1.

Example 1: Two-packer chamber installation assuming the working fluid level does not exceed the top of the chamber:

Well data: Total depth — 6400 ft; perforated interval from 6200 to 6400 ft; 5½-in. O.D. 17 lb casing set at 6400 ft; 2-in. tubing and dip tube; injection gas pressure = 600 psig; static

PRODUCING WITH J&L SUPPLY

Into the J&L warehouse at your elbow is funneled day by day and hour by hour the latest production-equipment experience from 91 stores, 22 sales offices, and a vast network of alert resident salesmen.

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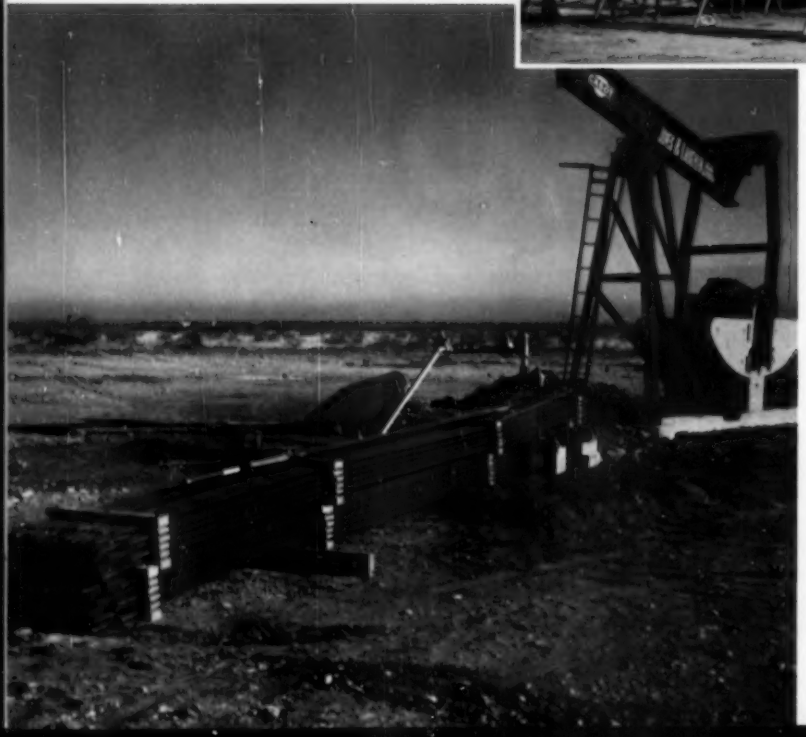
This well gets a second break — the tubing is also J&L! Non-upset and external upset in all API grades, and J&L Integral Joint. "JONES & LAUGHLIN SEAMLESS" rolled in or stenciled on casing and tubing is a comfortable assurance to careful buyers. Made by a manufacturer with more than 100 years of progressive experience. Sold by J&L Supply men intent on service.



This producer means business! The base is poured and a Cabot in place — the most satisfactory pumping unit known to the industry. To complete the picture — to give this well just about every safeguard and advantage in the book — the pump and rods are Axelson. The rods have been heat treated and normalized from end to end to make them strong, ductile, shock-resistant. The pump has been tailor-assembled in a nearby J&L shop to fit *this* well. (Axelson Hol-O-Rods, first with integral ends, are also prime favorites with producers who keep a weather eye on progress in equipment.)

Simple but greatly advanced design and construction, plus immediate J&L parts service, make Cabot pumping units the best buy in the United States and Canada. One-man crank balance. Patented rubber tail bearing — eliminates friction, needs no lubrication, absorbs shock and vibration. Sykes-cut herringbone gears, flood lubricated. Timken and Hyatt bearings. Powered here with a Century motor.

Another picture of how to pump for more profit. Cabot units serviced by J&L Supply hold the world's records for faithful performance. Maximum polish rod loads from 3,000 to 32,000 lbs. Standard equipment: floor clearing sub-base, V-belts, belt guards, adjustable slide rails. Powered in this instance with a Fairbanks-Morse "ZC" engine.

J&L

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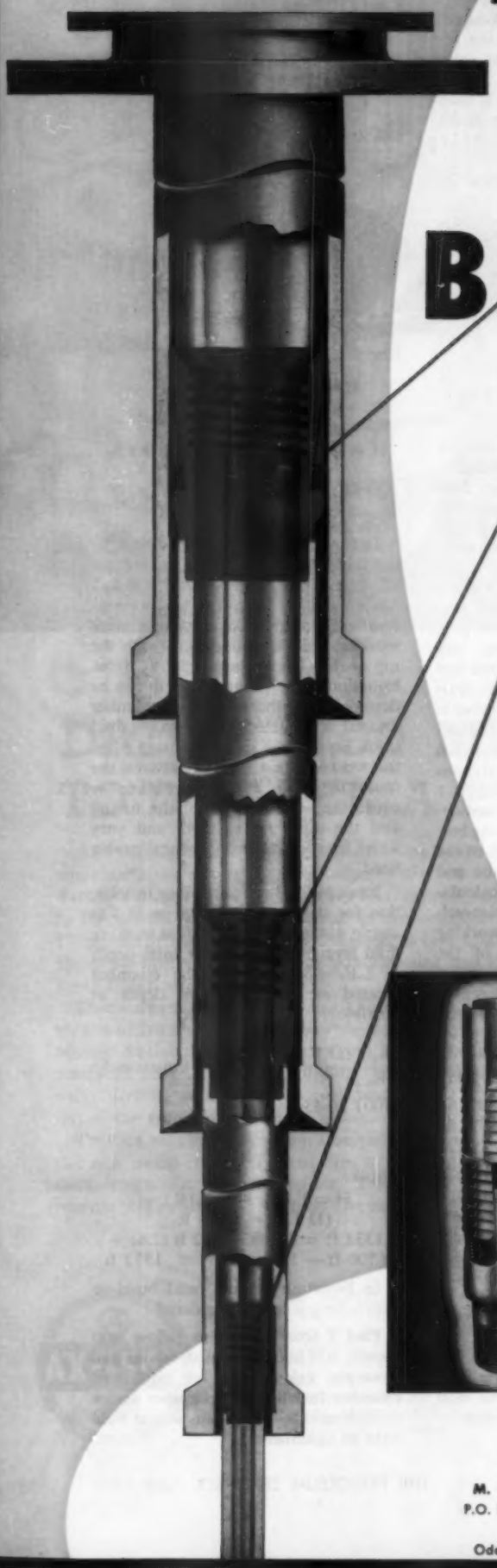

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3. SUSPEND OIL STRING
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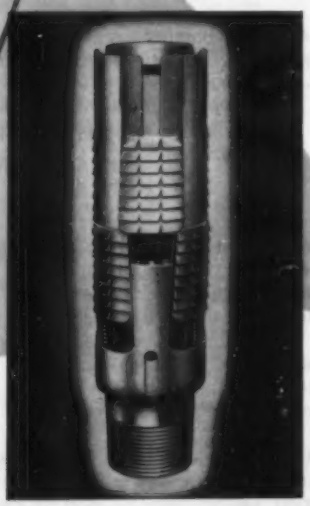

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fluid gradient = 0.4 psi/ft; and wellhead tubing pressure = 40 psig.

$$\frac{P_i - P_w}{S.G.} = C.L. + R.\ (C.L.)$$

$$C.L. = \frac{P_i - P_w}{S.G.\ (R + 1)} \quad \text{. . . . . (Equation 1)}$$

$$C.L. = \frac{600 - 40}{0.4\ (5.6)} = 250 \text{ ft Chamber}$$

Where:

$$R = \frac{V_{c\text{-}a}}{V_t} = \frac{17.8 \text{ bbl/1000 ft}}{3.87 \text{ bbl/1000 ft}} = 4.6$$

Check: Maximum head of fluid that the injection pressure will support.

$$H = \frac{P_i - P_w}{S.G.} = \frac{600 - 40}{0.4} = 1400 \text{ ft Maximum Head}$$

$$H = C.L. + R\ (C.L.)$$

$$1400 \text{ ft} = 250 \text{ ft} + 4.6\ (250 \text{ ft}) = 1400 \text{ ft}$$

Equation 1 is the conventional chamber formula applicable either to a two-packer or insert chamber. The chamber and dip tube are assumed to fill only to the top of the chamber in this equation. The tubing above the chamber is assumed to remain empty. The bottom packer is placed as near the top of the perforations as possible and the top packer 250 ft above it. In the case of an insert chamber, bottom of the chamber can be set near total depth. Therefore, the chamber length should be calculated by Equation 3, unless the working fluid level does not exceed the top of the chamber.

When the producing fluid level exceeds the top of the chamber, the conventional formula must be revised.

Example 2: Two-packer chamber installation for the same well data as in Example 1, except the maximum flowing bottom-hole pressure between injections is 300 psig, and the bottom packer is set at 6150 ft.

Maximum working fluid height = $\frac{P_f - P_w}{S.G.} = \frac{300 - 40}{0.4} = 650$ ft

Maximum working fluid level above bottom packer, F.L.B.

F.L.B. = 6150 ft —(6400 ft — 650 ft) = 400 ft

$$C.L. = \frac{P_i - P_w}{S.G.(R)} - \frac{F.L.B.}{R} \quad \text{. . . . . (Equation 2)}$$

$$C.L. = \frac{600 - 40}{0.4\ (4.6)} - \frac{400}{4.6} = 217 \text{ ft chamber}$$

Check: $H = F.L.B. + R(C.L.)$

$1400 \text{ ft} = 400 \text{ ft} + 4.6\ (217 \text{ ft}) = 1400 \text{ ft}$

In Equation 2, the maximum working fluid level is above the top of the chamber and the bottom packer is set 50 ft above the top of the perforations.

Example 3: An insert chamber installation for the same well data as in Examples 1 and 2, except 3½-in. nominal (4-in. O.D.) line pipe is used for the chamber, and the bottom of the chamber is near total depth.

$$C.L. = \frac{P_i - P_f}{S.G.\ (R)} \quad \text{. (Equation 3)}$$

$$C.L. = \frac{600 - 300}{0.4\ (1.73)} = 433 \text{ ft chamber}$$

Where:

$$R = \frac{V_{c\text{-}a}}{V_t} = \frac{6.7 \text{ bbl/1000 ft}}{3.87 \text{ bbl/1000 ft}} = 1.73$$

Check:

$$H = F.L.B. + R\ (C.L.)$$

$1400 \text{ ft} = 650 \text{ ft} + 1.73\ (433 \text{ ft}) = 1400 \text{ ft}$

In Equation 3, it is assumed that the bottom of the chamber is at total depth; therefore, maximum working fluid height in the well between gas injections is equal to the maximum working fluid level above the bottom of the chamber, F.L.B.

Insert chamber installation. When a well has several hundred feet of perforations or open hole and a low producing bottom-hole pressure, the packer must be set several hundred feet above the top of the chamber, as illustrated in Fig. 7 and 8. The chamber is set near total depth to obtain the desired drawdown. If a parallel injection gas line is used, the design calculations are the same as noted in Examples 1 through 3. The formula to be used depends upon the maximum working bottom-hole pressure and the depth of the chamber. When a small dip tube and hanger nipple are used, the calculations must include two annular-volume-to-tubing ratios if the working fluid levels exceeds the top of the chamber.

Example 4: Insert chamber installation, as shown in Fig. 7, with the top of the chamber located several hundred feet below the packer and the maximum working fluid level not exceeding the top of the dip tube (hanger nipple):

Well data: 4¾-in. ID open hole from 6000 to 6450 ft; 5½-in. OD 17 lb casing and 2-in. tubing; 1-in. dip tube 500 ft long; chamber of 3½-in. nom. (4 in. OD) pipe; depth of packer — 5950 ft; static fluid gradient = 0.45 psi/ft; injection gas pressure = 650 psig; and wellhead tubing pressure = 50 psig.

$$C.L. = \frac{(P_i - P_w) - D.T.L.\ (1 + R_{t\text{-}a})\ S.G.}{S.G.\ (R - R_{t\text{-}a})} \quad \text{. . . . . (Equation 4)}$$

$$C.L. = \frac{(650 - 50) - 500\ (1 + 0.57)\ 0.45}{0.45\ (2.6 - 0.57)} = 270 \text{ ft chamber}$$

Where:

$$R = \frac{V_{c\text{-}a}}{V_t} = \frac{10.1 \text{ bbl/1000 ft}}{3.87 \text{ bbl/1000 ft}} = 2.6$$

$$R_{t\text{-}a} = \frac{V_{t\text{-}a}}{V_t} = \frac{2.19 \text{ bbl/1000 ft}}{3.87 \text{ bbl/1000 ft}} = 0.57$$

Check:

$$H = \frac{P_i - P_w}{S.G.} = \frac{650 - 50}{0.45} = 1333 \text{ ft Maximum head}$$

$$H = D.T.L. + C.L.\ (R.) + (D.T.L. - C.L.)\ R_{t\text{-}a}$$

$1333 \text{ ft} = 500 \text{ ft} + 270 \text{ ft}\ (2.6) + 230 \text{ ft}\ (0.57) = 1333 \text{ ft}$

In Equation 4, it is assumed that the dip tube, chamber, and tubing annulus fill to the top of the dip tube. If the well has an extremely low producing bottom-hole pressure, and the maximum working fluid level does not reach the top of the chamber as calculated from Equation 4, the chamber length can be designed with the top of the chamber located at the maximum working fluid level. Equation 4 should be used when the working fluid level is between the top of the chamber and the packer because the volume between the tubing and the dip tube is small and very little feed-in represents considerable head.

Example 5: Insert chamber installation for the same well data as in Example 4, except the maximum working fluid level is 800 ft above total depth (F.L.B. = 800 ft with the chamber located as near the total depth as possible):

$$C.L. = \frac{(P_i - P_w) - [F.L.B. + R_{t\text{-}a}\ (D.T.L.)]\ S.G.}{S.G.\ (R - R_{t\text{-}a})} \quad \text{. (Equation 5)}$$

$$C.L. = \frac{(650 - 50) - [800 + 0.57\ (500)]\ 0.45}{0.45\ (2.6 - 0.57)} = 122 \text{ ft chamber}$$

Check:

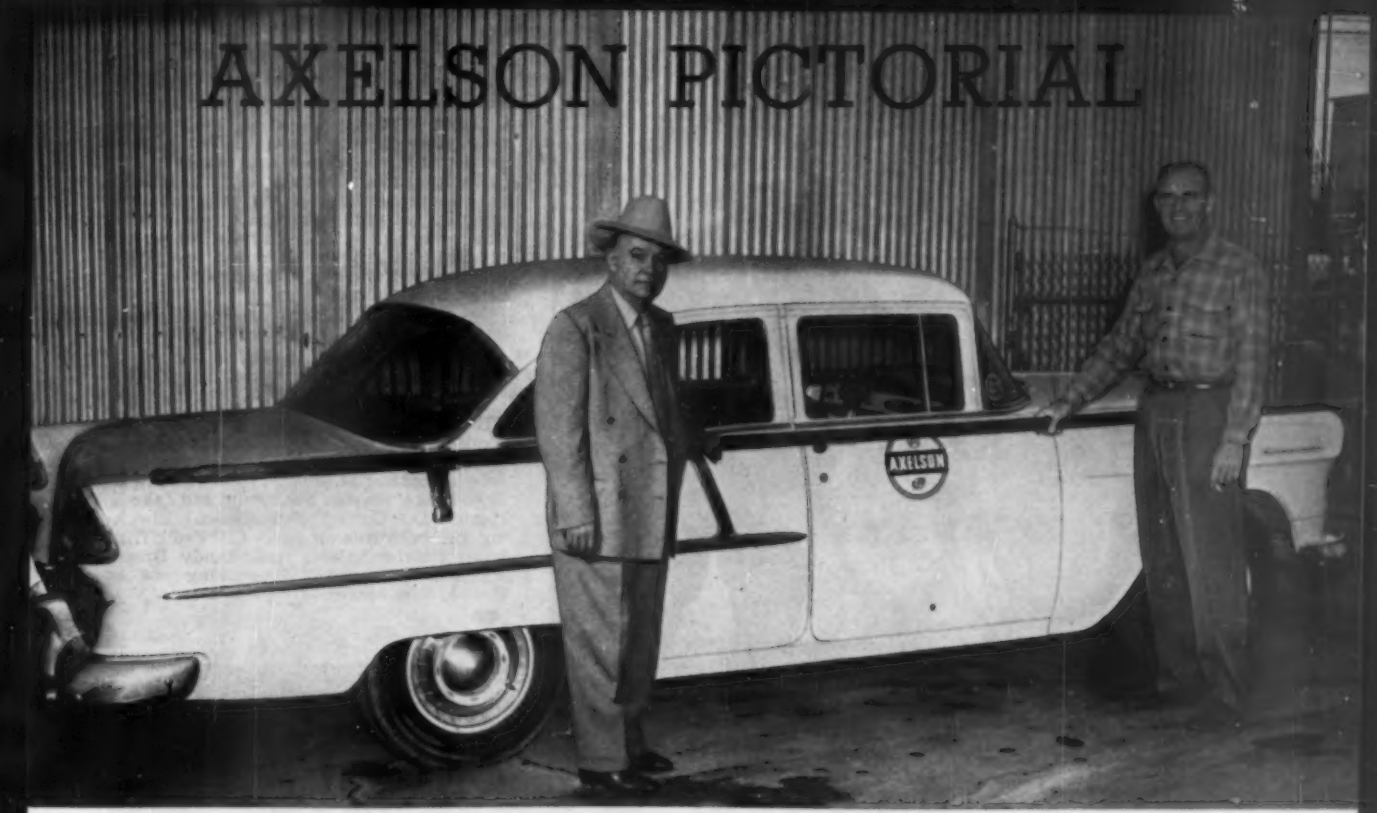
$$H = F.L.B. + C.L.(R) + (D.T.L. - C.L.)\ R_{t\text{-}a}$$

$1333 \text{ ft} = 800 \text{ ft} + 122 \text{ ft}\ (2.6) + (500 \text{ ft} - 122 \text{ ft})\ 0.57 = 1333 \text{ ft}$

In Equation 5, fluid head build-up above the packer is considered.

Part 2 (conclusion), to follow next month, will include considerations and example calculations for additional chamber installations, chamber design considerations, and some actual field data on chambers.

AXELSON PICTORIAL



SATISFIED CUSTOMER. Tad Travers (left) President of Brookline Oil Company, Los Angeles, shown with Don Moses, Axelson representative from Long Beach, who delivered the pump to Petrolia, California, 700 miles away. Travers says, "Axelson got us out of a bind. That's one outfit you can always depend on."

DRIVES 700 MILES TO DELIVER A PUMP

At Petrolia, California, (about 50 miles south of Eureka on the coast) the Brookline Oil Company had a well down. It was during a 3-day Labor Day holiday and no one could get a pump to them until after the week-end. In desperation, Tad Travers, President of Brookline, called Axelson in Los Angeles and told them the problem. The type of pump needed was located in the Long Beach store.

There was no way of getting it to the well by any available means of transportation. It was too big to go on a plane. So Don Moses, Axelson representative from Long Beach, strapped the pump to his car and took off for the location over 700 miles away. Driving non-stop, he arived just as the pump was coming out of the hole.

Travers was so glad to see Don pull up at the well site with the new pump that he cooked him a barbecue. "Axelson is one outfit you can always depend on," Travers says. "As far as our company is concerned, Axelson has no competitors."

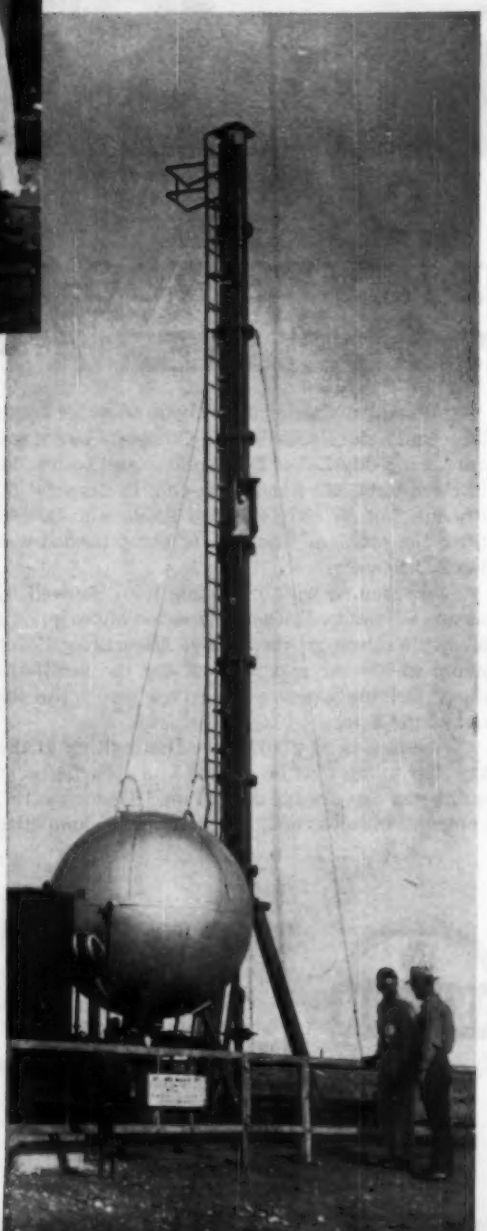
FRESH PUMP DELIVERY. The route taken by Don Moses on his non-stop journey from Long Beach to Petrolia. The first oilwell in California was drilled in Petrolia by Leland Stanford in 1864. Roads were so bad that well drilling equipment was shipped in by water. The oil (48 gravity) was called "rock oil" and was used for medicinal purposes. It was carried out in demijohns slung to the backs of mules.

A MILLION BARRELS. This is one of 4 wells on the Ralph E. Fair lease in Talco, East Texas. All are equipped with Axelson subsurface pumps and sucker rods. These wells have been pumping for 18 years and have lifted over a million barrels of oil *without once being pulled.* Checking the Batson #1 (46 B/D, 23 gravity, 4,150 ft.) are Willie Buchaman, Pumper (left) and Omer Cole, Lease Superintendent.

DEEP STUFF. At six strokes per minute, this Axelson Hydraulic Long Stroke pumping unit lifts 100 B/D of 48 gravity crude oil *from a depth of 11,500 ft.* (Well No. 1, R. K. Cone Lease, Warren Petroleum and Jake L. Hamon, Lea County, New Mexico). Checking the performance is T. C. "Ted" Tilgham, Pumper, (left) and Sandy Brock, Axelson Representative working out of Hobbs, New Mexico.

AXELSON

FIRST OFFSHORE. Drilled in 1864 by an Italian at El Salto, Peru, this well is believed to be the first offshore well in the world. Now the property of Empresa Petrolera Fiscal, it is still pumping. Axelson sucker rods are in service in this well and elsewhere in the field. Gross Equipment, S. A. is the Axelson distributor in Peru.



400 PUMPS. Lee Nave, Axelson Area Manager, sent in this picture of Axelson's pump repair crew at Lagunillas, Venezuela, in the middle of the Lake Maracaibo oilfields. He writes, "This crew was averaging 400 pumps a month at the time this picture was taken."

AXELSON PICTORIAL

HAPPY HUNTING. Last Fall, a group of oil men left Taft, California, for Utah where they bagged this 6-point buck (32¾" spread). It was the biggest deer reported in southwest Utah in '55. Left to right (standing): Red East, Standard Oil Company of California; George Napoleon, Socal; Harry Easton, M. H. Whittier Co.; (kneeling Gerald Parcel, Socal; Rod Napoleon (who shot the buck), Socal; Red Carroll, General Petroleum Corp.

BOOSTER. Taking inventory of the new gas booster installed by the Continental Oil Company in the Short Junction Field, is Harold Smith (left), Maintenance Engineer and Guy Lane from the Accounting Department at Ponca City, Oklahoma. This field is in Cleveland County about 15 miles southwest of Oklahoma City and is the hot spot in Oklahoma at the present. Continental Oil, a good customer for Axelson rods and pumps, has 65 wells producing from the Hunton Lime at 8,000' to 8,082'.

39 WELLS. Forest Oil Corporation has 39 wells in the East Goldsmith Field, Ector County, Texas, equipped with Axelson rods and pumps. Most are pumping from the Pennsylvania at 8,600', the rest are Holt production at 5,000'. A few flowing wells are scheduled to go on pump later in the year and Axelson rods and pumps have been specified. (Left to right) M. W. Johnson, Pumper; S. J. Ingram Jr., Space Hopper; S. J. Ingram Sr., Production Foreman; Gene T. Ingram, Door Slammer.

100%. Standing beside the T. M. Armstrong #24 at Gladewater, Texas, is Lloyd Stevens (left) Pumper, and O. B. Moon, Farm Boss. From the polished rod to pump shoe, this well is Axelson equipped: Axelson Kup-Pak pump (2½"x2"x12'), ¾" #60 Axelson Sucker Rod (3,600'), Axelson #60 (1¼"x11') polished rod, Axelson Stuffing Box, Marlo Packing. This packing has been running over 18 months without requiring replacement.

AXELSON PICTORIAL

TWO DOGS LONG. This is Consolidated Production Company's B-9 at Long Beach, California. An Axelson RLA top-lock pump, 2½"x 1¾"x 12', was installed November 26, 1941 *and has never been pulled.* It pumps low gravity crude oil (14.5) from the Ranger Zone at 2,550 feet. Axelson rods and stuffing box are also on the job. Talking shop (from left to right): Walt Lauerman, Lease Foreman; Gene Cook, Roustabout; Al White, Truckdriver. Walt says, "Ours is probably the longest and narrowest lease in the world. We call it "the Dachshund"– two dogs long and half a dog high."

18 CENT OIL. In 1933, Oklahoma operators objected to the proration laws of the state and forced the price of crude oil down to 18 cents a barrel. Governor William "Alfalfa Bill" Murray called out the National Guard and shut down 3,108 wells in a move to raise the price. When oil rose to 85 cents, the governor called off his militia. During these black days, the price dropped to 6 cents a barrel in East Texas. Photo (courtesy of Oil & Gas Journal) shows "Murray's Army" standing watch over wells in South Oklahoma City Field. Axelson pumps and rods have been producing Oklahoma City fields since oil was discovered there in 1928.

SINCE 1905. This J & L store opened in Bartlesville, Oklahoma, over 50 years ago and is the oldest oil supply location west of the Mississippi. It is part of a network of 91 J & L stores in the U. S. and Canada, selling and servicing Axelson equipment.

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Oil and Gas Development Approved in Alaska Area

APPROVAL of a Development Contract to encourage the search for petroleum in southern Alaska was announced recently by Acting Secretary of Interior Clarence A. Davis. The contract stems from 470 individual lease applications covering a 1,200,000-acre area in the territory.

The Development Contract between the United States and Colorado Oil and Gas Corporation of Denver, Colorado, was made pursuant to the authority contained in Section 17(b) of the Mineral Leasing Act of 1920, as amended. It culminates lengthy negotiations between the lease applicants and the Denver firm during which an Operating Agreement was concluded.

Of the 470 applications, 359 leases have been issued and the remainder are in various stages of processing, Davis has been advised. The leases are being issued in the Anchorage, Alaska, office of the Bureau of Land Management.

Lying between Icy Bay and Cape Fairweather, Alaska, part of the area involved is north and west of Yakutat and Disenchantment Bays while part is to the south and east.

Prompt and orderly exploration and development operations are needed in the area to secure locally, if possible, the supplies of oil and gas important to the territory, both for civilian and national defense purposes, Acting Secretary Davis pointed out.

The Colorado O. & G. contract is the third such agreement since 1953. A similar development contract was entered into with Phillips Petroleum Company covering about 1,000,000 acres in the Katalla-Yakataga are. A second but smaller contract with Standard Oil of California covered part of the Kenai Peninsula. It is estimated that exploratory expenditures of some $8,000,000 have been made under these two contracts.

Until 1953 there had been no oil or gas exploration work in Alaska since World War II except for operations carried on by the Navy Department in Naval Petroleum Reserve No. 4.

In negotiating an Operating Agreement, the Colorado company has agreed to accept the working-interest duties and obligations of the lessees under the leases covering lands committed to their operations.

Under the terms of the contract, Colorado Oil and Gas Corporation has agreed to expend at least $250,000 for exploratory work before April 1, 1957, and at least equal amounts thereafter before April 1, 1959, 1960 and 1961. Such expenditures are to include funds expended for geological, geophysical and other exploratory work and a credit towards the drilling of an exploratory well at a location to be selected by the operator with the approval of the Department of Interior Oil and Gas Supervisor. Drilling is to begin not later than July 1, 1959.

Each year during the term of the agreement (until 1966), the company is obligated to submit to the Supervisor a statement of its proposed program for the year, showing the methods to be used in exploratory and other operations, the particular localities in which operations are to be conducted, and of the area's remote location and the difficulty of access with attendant unusual and excessive expense and hazards, prompt approval of an operating, drilling and development contract was necessary in order to obtain orderly development in accord with the public interest of the United States.

The Development Contract is for a term of ten years unless sooner terminated by relinquishment or by cancelation for failure to carry out its provisions. ★ ★ ★

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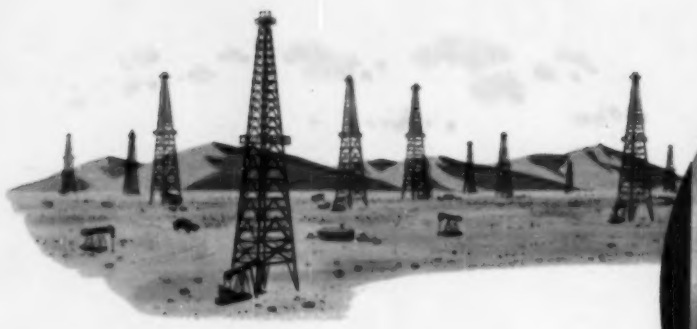

In golf it was Bobby Jones

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Its design and general construction can, has and will be copied, but THIRTY YEARS OF EXPERIENCE and KNOW-HOW in this field of endeavor are the exclusive property of FLUID PACKED PUMP CO.

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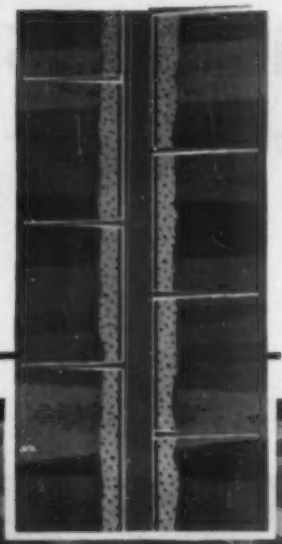
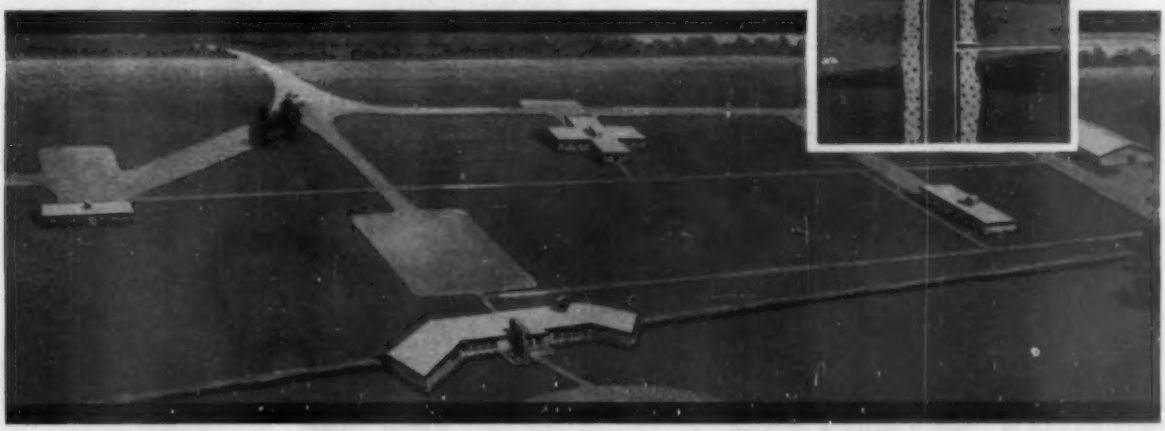
Announcing the Opening of World Headquarters for Jet Perforating Research





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Now in operation near Arlington is the most modern and complete industrial facility for jet shaped charge research and development. It is Jet Research Center, Inc., world headquarters for jet perforating research.

Jet Research Center has been created to serve all licensees and users of the jet shaped charge. Its purpose is easily defined . . . *greater perforating power through research.*

Utilizing the experience and knowledge of men who are specialists in this modern method of perforating, Jet Research Center will combine basic research with practical manufacturing techniques . . . will produce new and more potent jet charges for industry and government. Jet Research Center will also continue to finance fundamental research at the Poulter Laboratories of Stanford Research Institute.

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THE OASIS—

A gathering spot for NOMADS

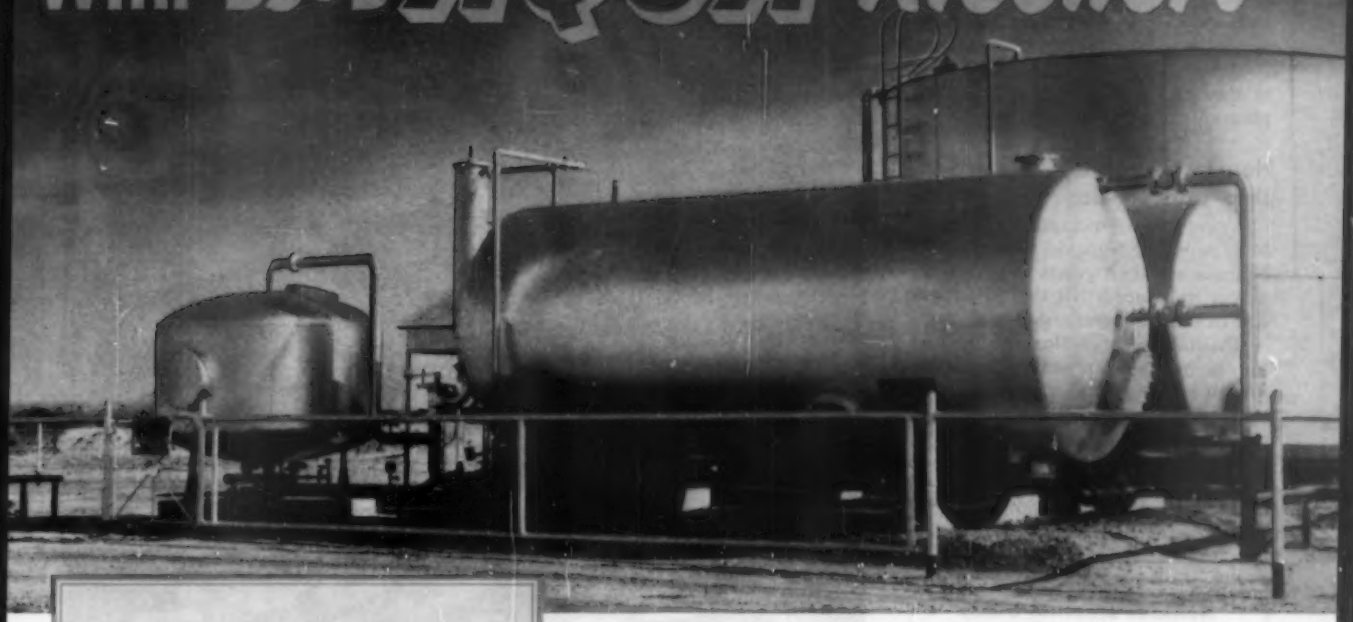
This cheerful group includes four of the international guests attending the regular monthly dinner meeting of the Houston Chapter of Nomads May 14. Shown are: G. A. Standish, drilling superintendent, Colombian Petroleum Corporation, Cucuta, Colombia; D. G. Hanwell, petroleum engineer, Iraq Petroleum Company, Ltd., Basrah, Iraq; H. G. Lindley, STOCA Drilling Company, Caracas, Venezuela, and Luis Moran, Petroleos Mexicanos, Mexico City.

Special meeting for Tulsa chapter was held April 4, where Nomads and their guests heard Brigadier General Stephen Longrigg of the Iraq Petroleum Company, give a most enlightening talk. His experience as Allied Governor General of the Italian-African Colonies after their capture makes him an authority on political and industrial affairs in the Near East. The group shown are (sitting): D. P. Hagaman, W. C. Norris Mfg.; R. C. Glover, Baker Oil Tool; L. A. Ogden, The Pure Oil; R. B. Thornburg, Jones & Laughlin; J. S. Hawley, Stanolind Oil & Gas; L. E. Patten, The Carter Oil; (standing) Arch Matheny, Republic Supply; T. A. Taggart, W. C. Norris; Ed. J. Jameson, The Carter Oil; C. H. Heplinger, Heplinger & Wanenmacher; Frank Purdum, Wright Petroleum Laboratories; Buford Penn, Sunray Mid-Continent Oil; R. E. Batchelor, Bovaird Supply, and Wm. L. Butler, W. C. Norris.

Eight past presidents of the Los Angeles Chapter were present at the April 11 meeting. They are (standing): Henry Pullman, Baker Oil Tools, 1943; Bob Eiche, R. J. Eiche and Associates, 1947; Bill Wilson, Web Wilson, 1952; Joe Schlarb, Emsco, 1954; (seated) Ted Sutter, Baker, 1940; Elmer Decker, Martin-Decker, first president, 1939; Harry Hester, McCullough Tool, present president; Ernie Fowks, Emsco, 1941.

International relations was the main topic of discussion at the Tulsa Chapter's March 30 meeting. Shown is main speaker Jenkin Lloyd Jones with Mrs. and Jack Beesley, Baroid, Dra. Dolores Prado, Petrobras geologist now on a study mission in the U. S., and Don L. Collins, Republic Supply.

Prevent Clogging of Water Injection Wells With BS&B AQUA-Kleener*!



AQUA-KLEENER FILTERS GIVE BEST RESULTS BECAUSE:

Permeable Underdrain Plates . . .

1. Eliminate filter bed disruption since only one grade of filter medium is required.
2. Prevent the filter medium from being carried out with the filtered water.
3. Serve as excellent flow distributors during backwash and allow more thorough cleaning of the filter medium. Channeling is eliminated.
4. Reduce maintenance because filter medium is not lost with the filtered water. Filter bed never has to be rebuilt because of disruption.

Removes Solids And Oil Traces From Water Without Chemical Treatment

AQUA-KLEENER conditions water for sub-surface injection, offshore disposal or surface disposal. Through an improved process of settling and filtering it removes oil traces and solid particles from lease-produced water, well water or surface waters and greatly extends the service life of water injection wells.

Each of the four components of the BS&B AQUA-KLEENER System—oil skimmer, filter, backwash tank and the BS&B "Filta-Wash"*—can be utilized separately or in various combinations as determined by the type of application and the degree of water conditioning required. Each can also be effectively utilized to improve existing installations.

Although the BS&B AQUA-KLEENER Filter can be used as a graded bed filter with efficiency at least equal to that of other systems, the recommended use of the filter with permeable under-drain plates and Anthrafilt No. 1 as the filtering medium will give longer filter runs and superior results at a much reduced maintenance cost.

* AQUA-KLEENER and FILTA-WASH are trade names of Black, Sivalls & Bryson, Inc.

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BLACK, SIVALLS & BRYSON, INC.

Oil & Gas Equipment Division, Dept. I-C6

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Los Angeles Nomads Plan Spectacular Whing Ding

Plans are now being made for the most fabulous Whing Ding ever offered by the Los Angeles Nomads, to be held this year on July 13 at the Lakewood Country Club. With a golf tournament planned for all — players who shoot 170 or merely 70 — with outstanding entertainment — with the congenial fellowship of other oil men in the area — this 1956 Whing Ding promises to be the greatest ever.

Houston Chapter's Membership Ranks Nearing Capacity

At the May 14 meeting of the Houston Chapter of Nomads, were some 70 Nomads and their guests were present, it was announced that the group was fast closing its membership ranks.

Chairman George Bloxsom reported for the membership committee that a total of 8 applicants had been approved by his group, and were being submitted to the membership to be voted upon. Should all of these men be elected, the Chapter will total 150 resident members, which is the maximum number allowed under the present by-laws.

Nomads Meeting Dates and Secretaries

New York Chapter, first Monday of the month, Hotel Roosevelt, New York. Executive Secretary, E. W. Hoeppner, in care of Hughes Tool Co., Room 4414, 30 Rockefeller Plaza, New York 20, N. Y.

Houston Chapter, second Monday. Ye Olde College Inn, Houston, Texas. Executive Secretary, Harry E. Estes, P. O. Box 18161, Houston 23, Texas.

Los Angeles Chapter, second Wednesday, Jonathan Club, Los Angeles, California. Executive Secretary, W. A. Sawdon, P. O. Box 848, Hollywood 28, Calif.

Tulsa Chapter, third Friday, Mayo Hotel. Executive Secretary, E. L. Thomas, P. O. Box 4033, Tulsa, Okla.

Dallas-Fort Worth Chapter, first or second Monday. Secretary, H. A. Davis, H. A. Davis Power Equipment Company, 2142 Irving Boulevard, Dallas, Texas.

About 190 Nomads and guests are shown here at the New York Chapter's annual invitation dinner at the Hotel Roosevelt. Principal speaker for the evening was J. Ed. Warren, vice president of the First National City Bank of New York. A. J. Kelly, Esso Standard Oil Company, acted as toastmaster.

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IN GRUELING TORQUE AND PRESSURE TESTS*

FOR CASING AND TUBING

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**Send for Technical Bulletin #3.1 describing pressure and torque tests.*

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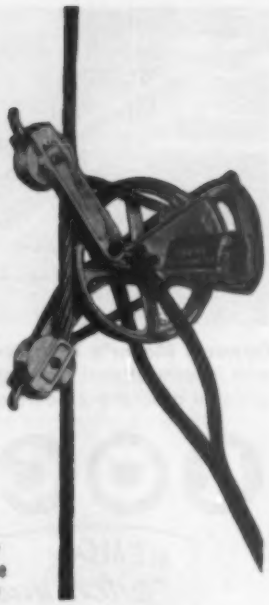
DEPTHOMETER

The ideal instrument for taking depth measurements with sand lines while bailing, swabbing, or running a single shot survey. Does away with "stringing-in."



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An entire lease is controlled accurately and precisely in a matter of minutes, right from the old rocking chair, through a battery of Willis Rotary Adjustable Chokes.

6 WAYS BETTER FLOW CONTROL

WILLIS Rotary Adjustable Choke provides 6 different sized choke inserts which are individually positioned in the line of flow by a fractional turn of the orifice-carrying disc... while under constant flow and high pressure. The 6 graduated orifices are changed to a new range of sizes in minutes... without shutting-in the well.

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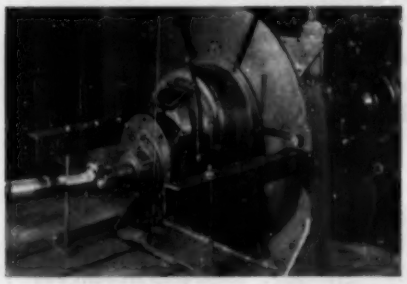
ROCKFORD POWER TAKE-OFFS are designed for generous overload capacity within the fields of service recommended by Rockford Clutch engineers.



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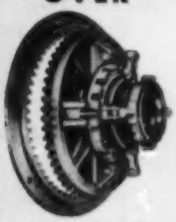

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Large ROCKFORD clutches, power take-offs and speed reducers are tested for torque, engaging pressure, release, temperature, gear strength, bearing endurance and clutch facing wear on this 400 H. P. diesel powered, electric dynamometer. Let ROCKFORD engineers utilize this machine to improve your heavy-duty power transmission controls.

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Clutch Division
BORG-WARNER
1303 Eighteenth Ave., Rockford, Ill.

CLUTCHES

GM Dedicates Giant Technical Center

On a closed-circuit television hook-up May 16, General Motors president Harlow H. Curtice dedicated GM's new multi-million dollar Technical Center at Warren, Michigan. Occupying 320 acres, the new research facilities included 25 buildings where more than 4000 engineers, researchers, stylists, designers, mechanics, machinists and other specialists will seek not only to improve today's techniques and products, but to look ahead. The Center was built with the idea that science is a source of economic energy for industry, the nation and the world. President Curtice said: "There are no 'todays' at the Technical Center. This is our investment in tomorrows."

Major facilities include: a 22-acre artificial lake, a 140-ft, 250,000,-gal stainless steel clad water tower, an aluminum sheathed Styling Auditorium with a 65-ft domed ceiling and 188-ft span, Gas Turbines Research building, Research Wind Tunnel, Research Isotope laboratory for work with radioactive material, test roads, and more than a mile of underground tunnels connecting the major Technical Center buildings. Construction began in 1949, and the first building was occupied in 1950. Last of the major units was completed late in 1955.

J. C. Trahan, Interests Form Drilling Firm

The American Metal Company, Ltd. and Cerro de Pasco Corporation, mining companies owning oil interests, and J. C. Trahan, an independent drilling contractor of Shreveport, Louisiana, today announced formation of a new company to engage in offshore drilling in the Gulf of Mexico. The new corporation, Trahan Exploration, Inc., will have executive offices in Shreveport, Louisiana, and an operations office in New Orleans, Louisiana.

Trahan Exploration, Inc. is expected to take delivery of the first drilling barge this fall. The barge, designed by Friede and Goldman, naval architects, will be of California-type design.

Designed to operate in water of maximum depth of 45-50 ft, the barge will be 180 by 136 ft and will have a vertical height of 66 ft. Its 2000 hp drawworks will be powered by a diesel-electric engine developing 2700 horsepower.

Officers of Trahan Exploration, Inc. are: J. C. Trahan, president; Thornton Tarvin, vice president; H. Danforth Starr, vice president; John Payne, Jr., vice president; Michael D. David, secretary; Hans Vogelstein, treasurer; George H. Cain, assistant secretary and assistant treasurer.

Set your sights on an HD-6G

for top performance
for top dependability
for top versatility

1½ yd bucket **55 belt hp** **19,600 lb**

Building fire wall dikes
Loading fill for building roads
Clean-up around drill site
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and all these exclusive on-the-job advantages important to both owners and operators . . .

Allis-Chalmers long-life diesel engine — power that handles tractor and bucket demands with ease.

Heavy welded-steel shovel side frames and low stabilizer — provide greater strength, low center of gravity, outstanding visibility.

Full-flow filtering — filters oil three ways, provides long-life protection for hydraulic system.

Six truck-wheel stability — almost 7 ft of track on the ground for superior balance.

1½-yd two-position bucket — handles big loads efficiently in loose material or hard-packed dirt.

All-steel, box-A main frame — soaks up shock loads, protects the entire power train.

One-piece steering clutch and final drive housing — line-bored for true alignment of shafts and gears.

Straddle-mounted final drives— with bearings on both sides of gears to maintain correct gear tooth alignment.

Simplified lubrication (including 1,000-hour lubrication intervals on truck wheels, idlers and support rollers) provides extra working time.

Unit construction—makes service easier, faster. Major units can be removed without disturbing adjacent assemblies.

Plus husky wrap-around radiator guard . . . simplified piping . . . heavy-duty truck frames . . . heavy-duty, roller-bearing truck wheels . . . matchless control . . . and the convenience of 24-volt direct electric starting.

Check the complete service program offered by your Allis-Chalmers construction machinery dealer. His factory-trained servicemen, factory-approved facilities, and stocks of True Original Parts keep your equipment operating properly . . . provide the kind of service that saves you money. See him soon; he'll be glad to show you an HD-6G at work.

ALLIS-CHALMERS, CONSTRUCTION MACHINERY DIVISION, MILWAUKEE 1, WISCONSIN

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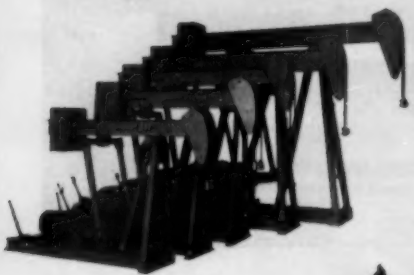
For compactness, light weight and ease of installation. Available in sizes ranging from 80,000 in. lbs. peak torque and 19,000 lbs. polished rod capacity to the mighty A-912DA-192-42 with 912,000 in. lbs. peak torque, 192 inch stroke and 42,000 lbs. polished rod capacity.



B BEAM BALANCED UNITS

Where economy is an important factor and dependability a prime consideration. Sizes from the B-10D-20-4 with 10,000 in. lbs. peak torque and 4,000 lbs. polished rod capacity to the B-57D-42-10.5A with 57,000 lbs. peak torque and 10,500 lbs. polished rod capacity.

C CRANK BALANCED UNITS

The all purpose unit known the world over for its ruggedness, trouble-free performance, and low cost maintenance. Sizes from the C-25D-24-6 with 25,000 in. lbs. peak torque and 6,000 lbs. polished rod capacity to the C-912DA-168-30 with 912,000 in. lbs. peak torque and 30,000 lbs. polished rod capacity.

Plus... LONG STROKE HYDRAULIC UNITS

For deeper wells and heavier fluid loads where high rod stresses are encountered. Rod life is greatly increased by this unit's slow, cushioned reversals and uniform polished rod velocity which avoids high peak loads. Available in 35,000 lbs. polished rod capacity and 20 ft., 25 ft., and 30 ft. stroke lengths.

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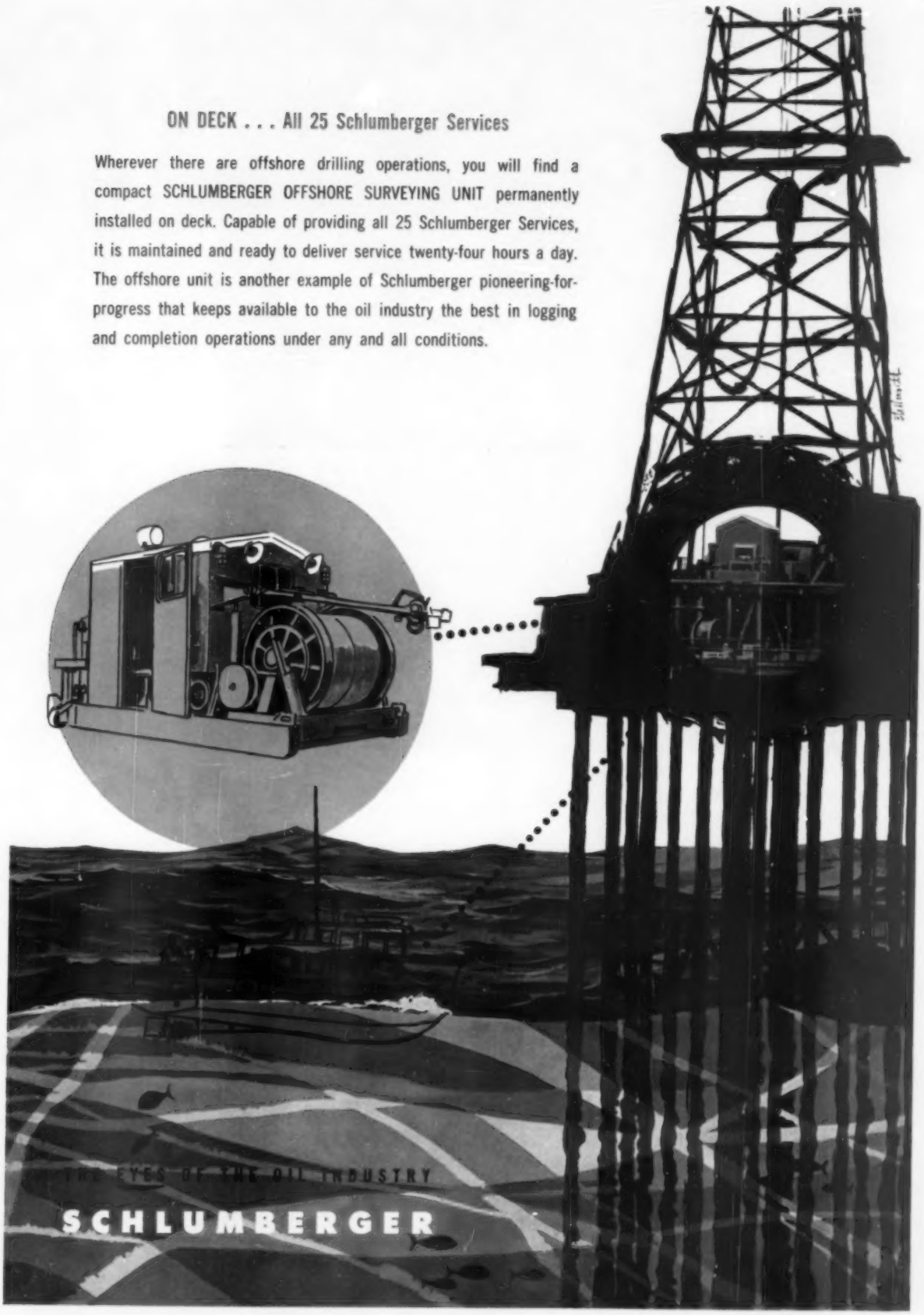
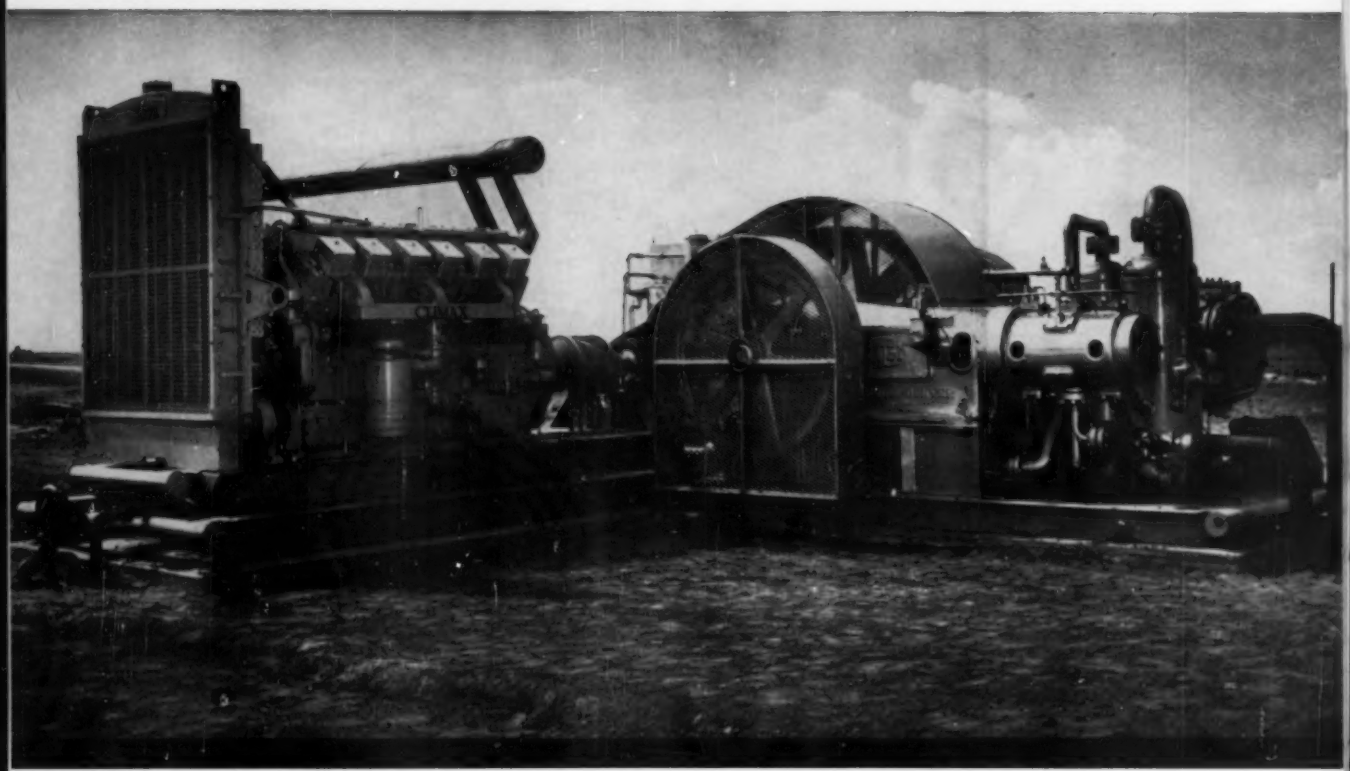


Rugged Performance



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INSTALLATION: Power for a major oil company's packaged gas compressor near Sterling, Colorado.

ANSWER: A Climax Blue Streak V-125, 12-cylinder natural gas engine.

This Climax engine operates at 1030 RPM, driving a Gardner Denver 13" compressor at 260 RPM, intake pressure 15#, first stage 130#, second stage 760#. Production is approximately 1,250,000 cubic feet of gas per day.

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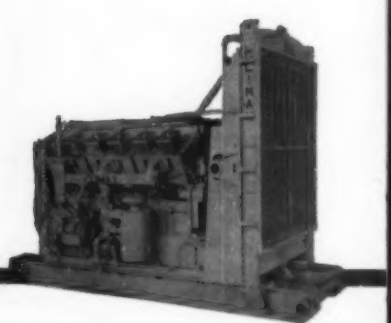

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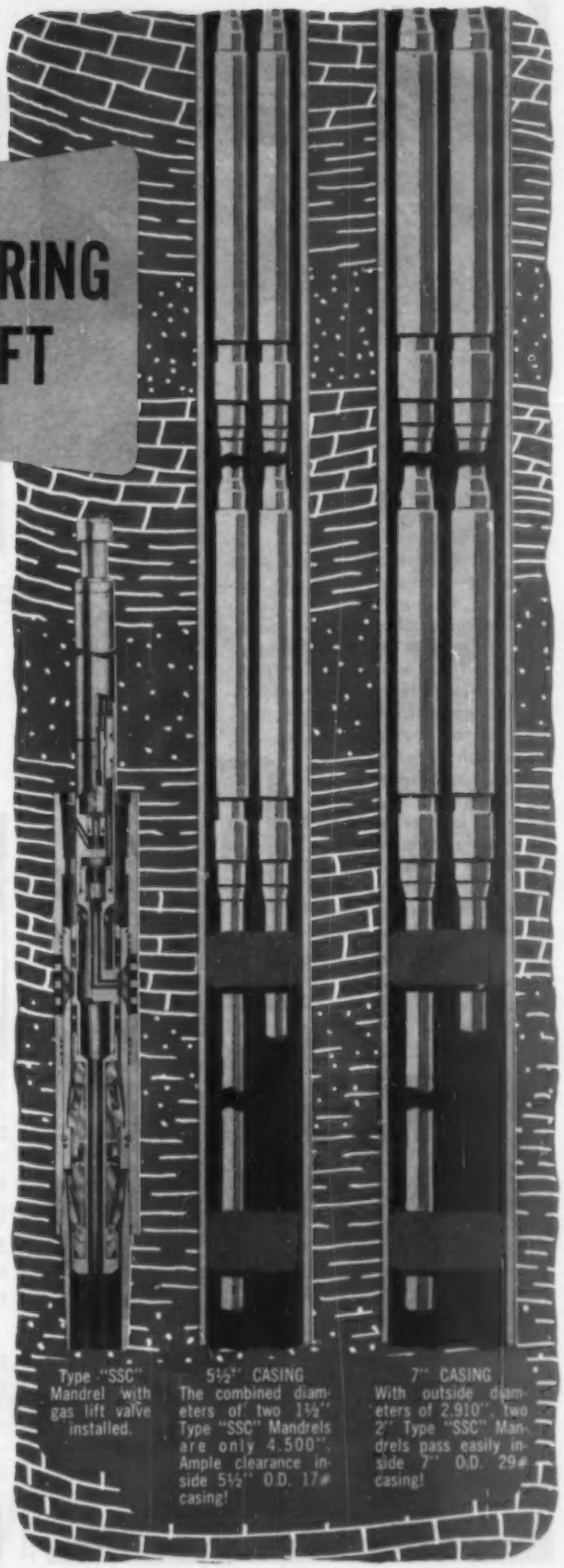
Many exclusive features found only in GOT Sleeve Valve Gas Lift combine to keep your lifting costs low throughout the life of the well.

Small diameter Type "SSC" Mandrels provide more clearance for fast running and pulling of either string, and serve also as full capacity circulating valves. Two strings of standard tubing may be used. All types of GOT pressure charged gas lift valves . . . bellows or piston . . . interchange in the mandrels, and may be installed or retrieved on one wire line run, without equalizing pressure. Undesired communication never exists between tubing and casing. Concentric valve receivers minimize turbulence, erosion and sand deposits, and facilitate engagement of the fishing tool. Mandrels are made of high strength, corrosion-resistant alloy, and contain no welding. Add to these features the **proved dependability** of GOT Pressure Charged Gas Lift Valves . . . and you have the most economical and most efficient dual completion gas lift installation available anywhere. Complete information and engineering assistance is available from your GOT representative or may be obtained from our Longview and Houston offices.


Type "SSC" Mandrel with gas lift valve installed.
5½" CASING
The combined diameters of two 1½" Type "SSC" Mandrels are only 4.500". Ample clearance inside 5½" O.D. 17# casing!
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With outside diameters of 2.910", two 2" Type "SSC" Mandrels pass easily inside 7" O.D. 29# casing!

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*More accurate than manual tank gauging

*Type "C" Metering Separators are dependably accurate to 99.99%.

Metering Separator, with intergral metering chamber, separates well fluid into oil and gas, meters each. Liquid is metered by cyclic accumulation type positive displacement method. Free water can be separated, metered.

Use as test unit at tank batteries—eliminate separate test tank, manual tank gauging. Use on dual completed wells to eliminate 2nd tank battery. Install at wellhead for continuous metering, well production control. Measure production for royalties, taxes.

High metering accuracy accomplished by consistent liquid control, proper valving. Simple, accurate, reliable pilots react at same levels for nonvarying unit volumes. Valves will not leak.

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SIZES AND CAPACITIES

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Vol. Per dump BBLS.	¼	½	1.0	2.0	5.0	10.0
Max. Oil Metering Cap. Bpd.	288	500	720	1100	2000	3000

Available in 125, 300 and 600 psi w.p.

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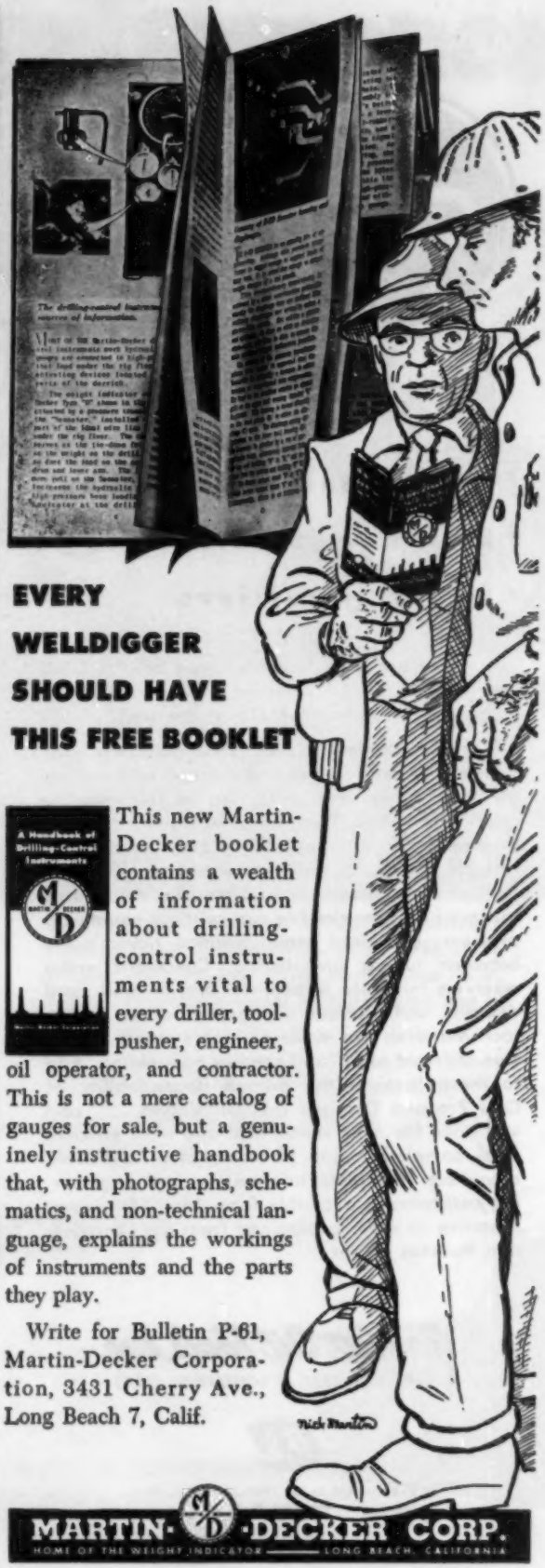

EVERY WELLDIGGER SHOULD HAVE THIS FREE BOOKLET

This new Martin-Decker booklet contains a wealth of information about drilling-control instruments vital to every driller, toolpusher, engineer, oil operator, and contractor. This is not a mere catalog of gauges for sale, but a genuinely instructive handbook that, with photographs, schematics, and non-technical language, explains the workings of instruments and the parts they play.

Write for Bulletin P-61, Martin-Decker Corporation, 3431 Cherry Ave., Long Beach 7, Calif.

MARTIN-DECKER CORP.

HOME OF THE WEIGHT INDICATOR — LONG BEACH, CALIFORNIA

Ohio Oil Forms Overseas Affiliate

The Ohio Oil Company has announced the formation of a wholly owned subsidiary, the Oasis Oil Company of Libya, which will be operator of some 35,000,000 acres of oil and gas exploration concessions in Libya, North Africa. Ohio Oil, Continental Oil Company and Amerada Petroleum Corporation each hold a one-third undivided interest in these Libyan concessions which in total area approximate the size of the state of Illinois.

The subsidiary will be in charge of geological and geophysical exploration and drilling on the concessions granted late in 1955 by the Libyan government. The land lies along the Mediterranean Sea and inland and is remembered as a World War II battlefield between the British Eighth Army and the German Afrika Corps.

Directors of Oasis of Libya are: P. L. Henderson, who is also president; F. J. Funk and H. C. King, vice presidents; H. H. West, secretary; and H. W. Stewart. C. A. Jackson is treasurer.

Resident manager at Oasis Oil's headquarters in Tripoli will be Albert F. Lager. He was former resident manager for the Conorada Petroleum Corporation, which conducted preliminary surface geological surveys and laid the ground work for negotiating concessions with the Libyan government.

V. L. Frost, formerly of Ohio Oil's Casper, Wyoming, production division, is named manager of exploration and R. M. Bone, formerly of Casper, geophysicist.

C. M. Deckard is controller. Deckard, formerly in the accounting department at Ohio Oil's general office, Findlay, will be located in Tripoli. T. C. Buchanan, formerly supervisor of Ohio Oil's Indiana transportation district, Indianapolis, will be manager of supply and transportation. These officials will headquarter in Tripoli.

Oasis will take over the former Conorada operating office in Tripoli and will later add some 14 geological and geophysical personnel.

Colombia Grants Mecom Offshore Venture Okay

Colombian government has granted approval of $20,000,000 offshore oil venture to John Mecom, Houston, Texas, independent operator. The operator has agreed to provide 75 per cent of the exploration investment, and the Colombian Oil Company (Ecopetrol) will furnish 25 per cent. Drilling equipment is expected to arrive in the next two months. For operations in the Tulo Bay and Morrosquillo Gulf areas.

It takes a lot of courage and a lot of money for Joe Roughneck to drill the oil wells necessary to supply ever-increasing demands. Despite fabulous stories . . about 7 out of 8 are dry holes.

But Joe, spirit of the oil industry, keeps drilling . . keeps bringing in wells . . to satisfy needs of the public, of industry and the Free World's defense. Lone Star Steel . . Joe's Friend . . is proud to supply the API pipe required by his stepped up drilling schedules.

Lone Star . . most modern pipe plant in the oil area . . turns out API quality casing, tubing and line pipe day and night for Joe's special needs.

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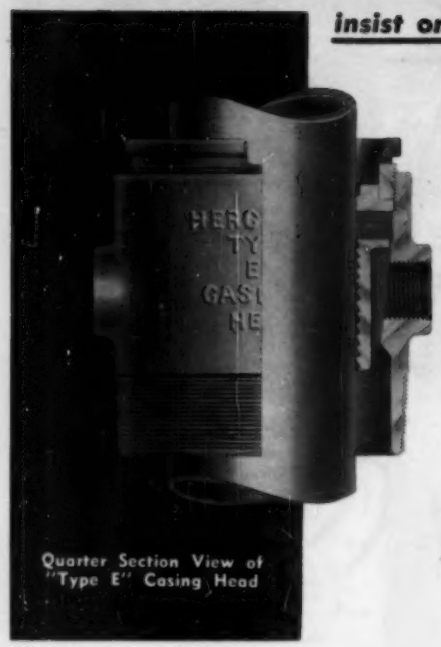
CASING STRINGS IN WELLS OF MEDIUM DEPTH AND PRESSURE



Quarter Section View of "Type E" Casing Head

insist on **HERCULES "TYPE E" CASING HEAD *(with slips)***

Constructed from pressure cast steel and hydrostatically tested to 3000 psi. Pack-off is accomplished with Hercules ORIGINAL OVERHEAD PACKING. The three-piece hinged slips insure even gripping action and facilitate installation. All sizes are full-opening, allowing passage of centralizers, packets, etc. The packing nut acts as a thread protector and is provided with notches to accommodate a wrench or pinch bar. The recommended maximum load is 200,000 lbs. Write for complete information and range of sizes.

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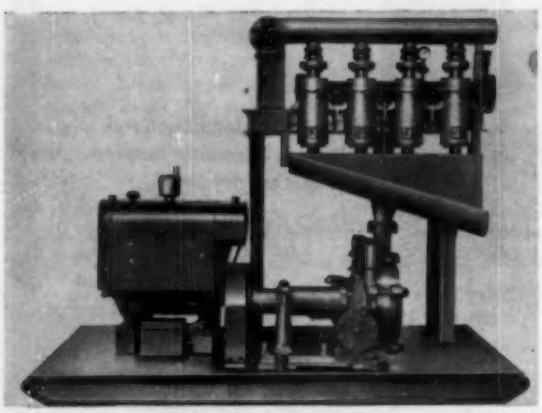
Export Representative: Oil Field Equipment Co., Inc., 30 Church Street, New York 7, N. Y.



The DORRCO MUD D-SANDER

A new device for removing sand and abrasive solids from drilling mud.

- Up to 20% faster drilling
- Increases bit footage
- Greatly reduces pump maintenance
- Casing runs easier

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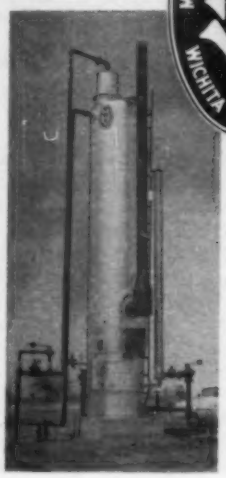
Specify . .



TYPE P-V

PRESSURE TREATERS

M & V Pressure Treaters have an unbeatable record of trouble-free performance. They are designed to operate automatically with a very minimum of supervision . . . built to the most exacting standards . . . and offer you the finest possible assurance of full recovery at lowest cost.

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Steel Fabrication for the Oil Industry

Four Times Longer Life*

from Ampco Polished Rod Liners

...with fewer shut-downs for repairs, less loss of production, lower maintenance costs.

You can retard mechanical wear, corrosion and erosion with Ampco polished rod liners. Even in many of the toughest oil-well services, you can get four times longer life with these remarkable wear-resistant liners—made from Ampco Metal.

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*Name of this user upon request.

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PR-22

EXPLORATION ACTIVITIES

CALIFORNIA

★ Moriqui Exploration Company has spudded a new test in Butte County about five miles south of the Durham field on Sec. 31, 20-1. The operator plans to explore for the Donahoe gas sand which is productive in the Durham field. The company has approximately 3500 acres under lease in the area, while Standard Oil of California and Humble Oil & Refining hold adjoining acreage.

★ The Texas Company has completed Arthur Brown (NCT-1) No. 2 one mile northeast of production in the Georgiana Slough area of Sacramento County for a new pool discovery. The well was drilled to a total depth of 4750 ft and plugged back to 3314 ft where it was completed for initial output of 2,000,000 cu ft of gas daily through a 5/16-in. choke.

★ Shell Oil Company is under way with a new wildcat about one-half mile northwest of production in the Canal field in Kern County. The new test is KCL No. 77-10 and will seek production either in the Basal Stevens or Vedder zones, both of which were proved productive last year in the nearby Strand field. In the meantime, two and one-half miles to the northeast of the wildcat Shell has spudded Posuncula-KCL No. 7, a development well in the lucrative Posuncula discovery area at Strand.

★ C. W. Colgrove is drilling a deep test about one mile northeast of production in the Plovadero pool at the southeastern tip of the Guijarral Hills field in Kings County. The well is the Bordogaray No. 18-30, programmed for a depth of 12,000 ft to explore for production in the Gatchell sand.

★ Harry H. Magee, operator, made a new oil discovery on the James Breen ranch in the Flint Hills about four miles northwest of Hollister in San Benito County. The well is a redrill of one put down to 4591 ft in 1953 by Tidewater Oil Company. It was completed by Magee for flowing production of 250 bbl per day of 35 deg gravity crude oil from a depth of approximately 4000 ft.

Edwin W. Pauley has completed a complicated, 500-acre leasing play between Pico Boulevard southerly to the Pacific Electric tracks near the city limits of Culver City in the area of Hillcrest Country Club, and is expected to drill shortly. The well site will be in Culver City on a three and one-half-acre site on Pacific Electric property, and the hole will be directionally drilled under the leases in Los Angeles. The property involves the old Las Arnez Ranch on which Standard Oil Company of California started a well 30 years ago but failed to complete when the city revoked its drilling permit after the well had reached a depth of 1000 ft. Pauley's well is expected to test possible productive zones between 3000 and 8000 ft. Hill Oil Company and Aladdin Oil Company both have interests in the play.

★ Bahama California Oil Company, subsidiary of Standard Oil Company of California and Bahama Exploration Company, Gulf Oil subsidiary, have begun a joint marine seismic survey of the 1700-square-mile Cal Sal area, which lies approximately 200 miles southwest of Nassau. The venture marks a continuation of the exploration efforts which both companies have been conducting in this area for several years. The new survey will be conducted under contract by Western Geophysical Corporation under supervision of Bahama California Oil.

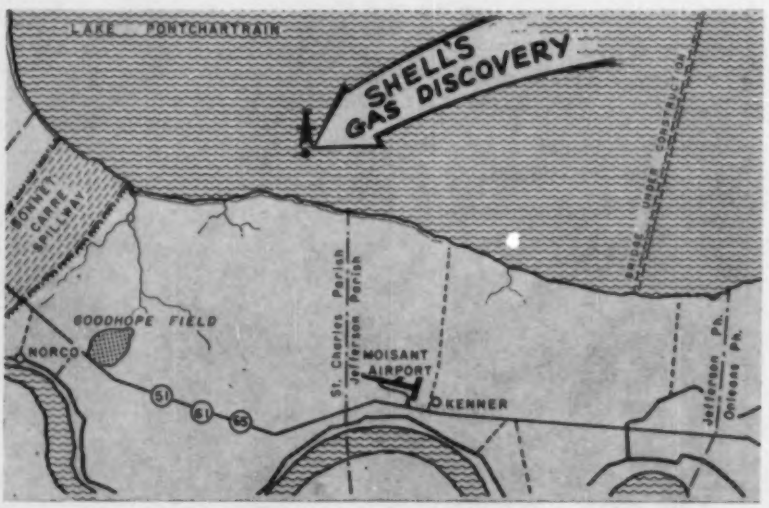
ALASKA

★ Colorado Oil and Gas Corporation has acquired oil and gas leases covering approximately 1,000,000 acres of Federal lands in southeastern Alaska. The area lies along the Gulf of Alaska between Icy Bay and Cape Fairweather in the Alaska panhandle north of Juneau. The leases were acquired under operating agreements with some 265 individuals having Federal oil and gas leases. The development contract with the government requires exploration expenditures of $250,000 before April 1, 1957, with equal amounts required to be expended before April 1 in 1959, 1960 and 1961.

The leased area extends along some 140 miles of generally flat, coastal terrain containing surface seeps of 30 deg oil as well as gas. Work will commence June 1 and the first year's activity will be devoted principally to geological mapping by seismograph and surface reconnaissance.

LOUISIANA

★ Shell Oil Company's rank wildcat well in the southwest end of Lake Pontchartrain has discovered new gas production. On a drillstem test the well, State Lease 2918 No. 1, produced at a daily rate of 1,600,000 cu ft of gas through a one-eighth inch choke from the interval of 8808 to 8824 ft and tubing pressure of 3375 psi. The well is four miles northwest of Moisant airport in Lake Pontchartrain Block 41, which Shell leased from the state last January. It is 6000 ft from shore in water 12 ft deep. Drilling was done by the Continental Drilling Company, which spudded in the hole March 3. The well was drilled to a total depth of 10,984 ft. The only other production in Lake Pontchartrain is 24 miles away in the Big Point field at the northeast end of the lake. The nearest production is on land in the Good Hope field about four miles to the southwest. The discovery is shut in.



SHELL'S NEW GASSER, State Lease 2918 No. 1, drilled by Continental Drilling Company, is 24 miles from nearest production.

The money on the left illustrates barrels of oil recoverable from a reservoir through ordinary, rule-of-thumb methods. All formation information is assumed. No core analysis and associated reservoir engineering costs are involved. Total recovery from the reservoir "just happens" and the operator is "home free."

The money on the right represents maximum ultimate recovery . . . *from the same reservoir* . . . effected through Core Lab's modern technical methods. Basic formation information is obtained through direct analysis. Engineered control is established and applied throughout the productive life of the reservoir.

What are the costs involved? Only one or two of those silver dollars, compared with the gain as illustrated — that's all the operator must spend.

Penny-wise, barrels foolish? Or maximum ultimate recovery? It's your choice.

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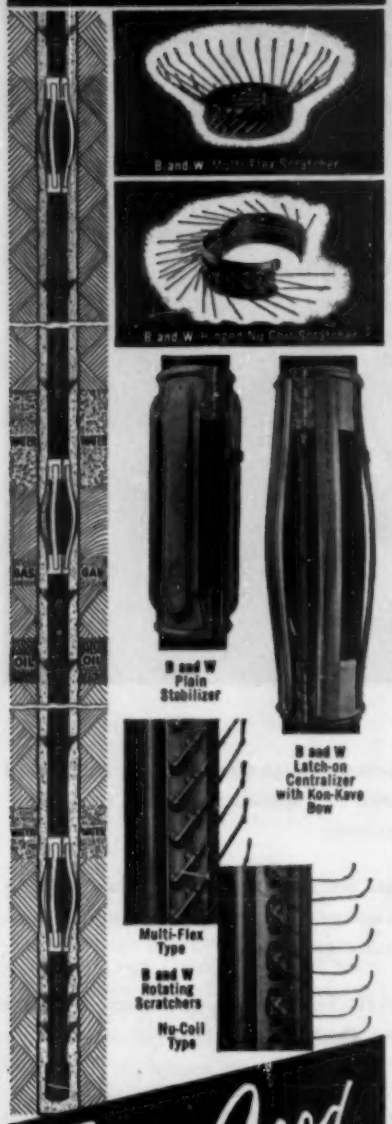
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8-404

Exploration

LOUISIANA

★ Union Oil Company today reported a flowing oil well in its Aristile Landry 1 wildcat in Assumption Parish. Located about one mile north of the Amelia gas field, the well on a 6-hr test flowed clean 36.4 gravity oil at the rate of 345 bbl a day through a 9/64-in. choke, with 3520 psi tubing pressure. Production is from one of several known producible sands in the well, with perforations from 12,666 to 12,673 ft.

★ Southern Production Company, Phillips Petroleum and J. Ray McDermott & Company are drilling a 14,000-ft wildcat in the Gulf of Mexico off Terrebonne Parish under a farmout agreement with Magnolia Petroleum Company covering a 2500-acre lease. The well, Southern Production's initial exploratory venture into the tidelands, is being drilled by Drill Barge No. 52 of the Offshore Company, a 67.55 per cent-owned subsidiary of Southern Production. The test, Magnolia "F" No. 1, is located on State Lease No. 767 in the eastern half of Block 73, Ship Shoal Area, in approximately 25 feet of water.

KANSAS

★ Cities Service is completing its Lansing-Kansas City pool discovery in Decatur County for an initial of 330 bbl of oil daily. The company also announced location of a second test well two miles west of the discovery. The discovery is Warner E No. 1 and it is located on a 2400-acre block owned wholly by Cities Service. The well is 20 miles north of the Jennings pool and approximately 14 miles northeast of Oberlin, Kansas near the Nebraska border.

The initial is based on an eight-hour test in which the well produced 110 bbl of 34.6 gravity oil in eight hours from Lansing-Kansas City perforations between 3324 and 3333 ft.

★ White Eagle Oil Company has discovered Morrow sand and Mississippian lime crude production in a Kearny County wildcat. The well, No. 0-4 White, is about 5 miles north of Pleasant Prairie field in Haskell County. The test topped the Atoka at 4805 ft, the Morrow at 4860 ft, and the Mississippian at 4980 ft. Operators were last reported coring ahead below 5000 ft., following good cores and shows in the Morrow and Mississippian. White Eagle has some 35,000 acres under lease in the area.

BOLIVIA

★ An exploration agreement between the Bolivian government and Bolivian Gulf Oil Company are now being completed. Oil exploration problems are being discussed by officials of Yacimientos Petroliferos Fiscales Bolivianos, the government oil agency, and officials of Falcon-Seaboard Drilling Company, part owner of Bolivian Gulf Oil. The latter recently obtained exploration privileges on nearly 8,000,000 acres of Bolivian land.

A letter of agreement has already been signed, wherein Bolivian Gulf has offered to finance $5 million of a proposed $10.5 million pipe line.

Formal signing of the contract is expected to take place while these Falcon-Seaboard officials are in Bolivia.

The discussion of exploration problems will help Falcon-Seaboard make plans for future drilling activity in that area.

Part of the negotiations include the 201-mile pipe line, highest in the world, which will carry Bolivia's surplus production to a port on the Pacific Coast of Chile.

TEXAS

★ Discovery allowable has been granted Nortex Gas & Oil Corporation at its J. L. McMenamy lease in Grayson County. On 24-hour initial potential test, well showed 101 bbl of oil cut 20 per cent with water from perforations at 2122-70 ft. This new discovery is producing from a 50-ft limestone section present in nearly every well drilled in the South Grayson County area. Prior tests in the section did not prove productive until the McMenamy was brought in. Drillstem testing from 2129-2209 ft with the tool open for 54 minutes produced a fair to strong blow recovering 2100 feet slightly muddy oil and 30 feet of salt water. Nortex has named the new field McMenamy "K" Limestone Field.

Seagoing OIL RIG

For complete information, write:
The INGALLS Shipbuilding Corporation
Birmingham, Alabama

Men and equipment team up

for the record!

On December 6, 1955, Richardson and Bass Rig Number 25 drilling the Richardson and Bass (Louisiana Account), John W. Mecom, and Freeport Sulphur No. 1-L, LL&E-State Lease 2414, a Lake Washington wildcat in Plaquemines Parish, Louisiana, spun a Reed Rock Bit into a sand and shale formation at a total depth of 22,559 feet . . . the deepest point man has ever penetrated the earth.

It is a tribute to the courage of the men who made the decision to drill the well and to the entire oil industry that this unprecedented depth was reached in a commercial venture, paid for by risk capital earned under a free enterprise system. The discovery of new oil producing horizons at such depth could add greatly to our nation's store of natural resources.

The world's deepest well is a significant credit to the men who backed it, the men who drilled it and, in smaller measure, to the manufacturers who made the drilling tools.

(Note) On January 8, 1956, a Reed Rock Bit was used to deepen the hole eleven feet to a total depth of 22,570 feet.

REED

ROLLER BIT COMPANY

HOUSTON 1, TEXAS

NEW YORK LONDON BUENOS AIRES

Richardson and Bass crews drill world's de using Reed Rock Bits

On the page opposite are pictured the handful of men whose skill and ingenuity in handling rotary oilwell drilling tools enabled them to drill the world's deepest well. With Richardson and Bass Rig 25 they drilled 22,559 feet into the earth without making the slightest error which could have resulted in serious trouble or loss of the hole.

73 REED ROCK BITS USED

Shown below are the last five used from 22,027 feet to 22,559 feet. Sixty-three Reed cross roller Rock Bits were used below 14,000 feet. (See complete bit record on next page.) Three Reed Drill Collars were used in the drill string.

(Note) On January 8, 1956, a Reed Rock Bit was used to deepen the hole eleven feet to a total depth of 22,570 feet.

REED

epest well

most of the way!

G. G. "Pinky" Jordan, toolpusher, a veteran Richardson and Bass hand whose job it was to keep Rig 25 "drilling ahead" on the record-setting well.

Crew, Rig 25, left to right: F. A. Mobley, helper; M. J. Gondrella, derrickman; J. E. Steinwinder, driller; E. N. Steele, Jr., helper; B. S. Whitfield, helper; W. C. Jackson, fireman.

Rex Haile, left, and Bill Kenny, right, Richardson and Bass mud engineers who were on duty alternately each day Rig 25 was drilling the world-record well.

(Above) Crew, Rig 25, left to right: L. J. Breaux, derrickman; T. V. Wallace, fireman; Billy Van Winkle, driller; E. W. Warrick, helper; R. D. Mark, helper; S. E. Eilington, helper.

(Right) Crew, Rig 25, left to right: M. B. McDaniel, welder; T. A. Hambrice, helper; George Fruge, fireman; L. J. Seneca, derrickman; C. V. Peeler, helper; H. D. Wright, driller; R. C. Wright, helper.

Shown above are three 4½-inch O. D. Reed Drill Collars used in the drill string on Rig 25 while drilling the world's deepest well.

ROLLER BIT COMPANY

HOUSTON 1, TEXAS

The record speaks for itself!

FORM NO. JD-101
1/1/53

SPUDDED: 2-27-55
UNDER SURFACE: 3-3-55
✓ INTER: 9-16-55
22,559': 12-6-55

A.P.I. BIT QUESTIONAIRE

Oil Company RICHARDSON & BASS (Co. Acct.) Well L.A. LAND & EXPLORATION #1-L Contractor SAME RIG #25

Date Spudded FEB. 27, 1955 Field ~~BOOTSTRAP~~ LAKE WASHINGTON WILDCAT County PLAQUEMINE State LA.

Drill Pipe O.D. _____ Tool Joint Type _____

Type Rig - Steam ✓ or Power _____ Mud Type LIME BASE OIL EMULSION 10% OIL

Drill Collars { Length 90 O.D. 8" I.D. _____ Interval 0-13665
Length 90' O.D. 5¾" I.D. 4⅛" Interval 13665-19752, 19752-22559

5 LUCEY 150 BOILERS STEAM PRESS - 350 PSI

TOOL PUSHER -

Observed Data

Bit no.	Bit Size	Bit Mfgr.	Bit Type	Jet-vj Reg-d	Watercourses No.	Watercourses Size	Depth Out	Footage	Hours Drld.	Feet per Hour	Bit Weight (000 #)	Table RPM	Mud Wt.	Mud Vis.	Deviation	Pump No. Liner	Pump No. SPM	Pump No. GPM	Pump No. Liner	Pump No. SPM	Pump No. GPM	Pump * Operation	Pump Press.	Total GPM	Nozzle Vel.
1	26	HUNT	3-WAY				300																		
2	12¼	HTC	OSC-3	J			3007	2707	11¾														1600		
3	17½	REED	2-CTTE																						

Observed Data

Bit no.	Bit Size	Bit Mfgr.	Bit Type	Jet-vj Reg-d	Watercourses No.	Watercourses Size	Depth Out	Footage	Hours Drld.	Feet per Hour	Bit Weight	Table RPM	Mud Wt.	Mud Vis.	Deviation	Pump No. Liner	Pump No. SPM	Pump No. GPM	Pump * Operation	Pump Press.	Total GPM	Nozzle Vel.
41	12¼	REED	LT-3	J	2	¾	12917	104	18¾													
42	✓	HTC	OSC-3	J			13032	115	13¾													
43	✓	✓	✓	✓			13189	157	16													
44	✓	✓	✓	✓			13326	137	16¾													
45	✓	✓	✓	✓			13584	258	26¼													
46	✓	✓	✓	✓			13665	81	12													
47	✓	✓	✓	✓	RERUN		13665			CIRC												
48	8⅜	REED	T	✓	2	¾	2 x-ov			DRILL												
49	✓	✓	✓	✓	✓	✓				TRIP												
50	✓	✓	✓	✓	✓	✓	13838	173	25¼													
51	✓	HTC	OSC-3	✓			14049	211	27¼													
52	✓	REED	T	✓	2	3/16	14366	317	40½													
53	✓	✓	✓	✓	✓	✓	14562	196	26													
54	✓	✓	✓	✓	✓	✓	14842	280	40													
55	✓	✓	✓	✓	✓	✓	15064	222	38½													
56	✓	✓	✓	✓	✓	✓	15265	201	27¾													
57	✓	✓	✓	✓	✓	✓	15482	217	36½													
58	✓	✓	✓	✓	✓	✓	15709	227	38													
59	✓	✓	✓	✓	✓	✓	15985	245	45													
60	✓	✓	✓	✓	✓	✓	16197	212	38													
61	✓	✓	✓	✓	✓	✓	16422	225	38¾													
62	✓	✓	✓	✓	✓	✓	16638	216	35½													
63	✓	✓	2HM	✓	✓	✓	16763	125	23½													
64	✓	✓	2HS-1	✓	✓	✓	16959	196	34½													
65	✓	✓	2HM	✓	✓	✓	17116	157	27½													
66	✓	✓	✓	✓	✓	✓	17306	190	35½													
67	✓	✓	✓	✓	✓	✓	17427	111	23¾													
68	✓	✓	2HS-1	✓	✓	✓	17567	135	25½													
69	✓	✓	✓	✓	✓	✓	17677	110	19													
70	✓	✓	✓	✓	✓	✓	17791	114	20¼													
71	✓	✓	✓	✓	✓	✓	17900	109	22¾													
72	✓	✓	✓	✓	✓	✓	18015	115	33													
73	✓	✓	✓	✓	✓	✓	18265	190	32½													
74	✓	✓	✓	✓	✓	✓	18466	201	38													
75	✓	✓	✓	✓	✓	✓	18606	140	27½													
76	✓	✓	✓	✓	✓	✓	18705	99	21½													
77	✓	✓	✓	✓	✓	✓	18935	230	47													
78	✓	✓	✓	✓	✓	✓	19116	181	40½													
79	✓	✓	✓	✓	✓	✓	19343	227	42¾													
80	✓	✓	✓	✓	✓	✓	19550	207	38½													

* Pump Operation: S - Single; P - Parallel; C - Compound.
** Hydraulic HP based on 85% Efficiency.

Observed Data

Bit no.	Bit Size	Bit Mfgr.	Bit Type	Jet-vj Reg-d	Watercourses No.	Watercourses Size	Depth Out	Footage	Hours Drld.	Feet per Hour	Bit Weight	Table RPM	Mud Wt.	Mud Vis.	Deviation	Pump No. Liner	Pump No. SPM	Pump No. GPM	Pump * Operation	Pump Press.	Total GPM	Nozzle Vel.
81	8⅜	REED	2HS-1	J	2	¾	19743	193	38													
82	✓	✓	✓	✓	✓	✓	19752	9	2	RE-RU												
83	6	✓	2C	R			17422	1444	30													
84	✓	✓	✓	✓			18837	1415	30	DRILLI												
85	✓	✓	T	✓			19690	853	20½	CEMEN												
86	✓	✓	2C	✓	2 DRILLING UP																	
87	✓	✓	✓	✓	2 PACKERS, CONDITION HOLE ETC.																	
88	✓	✓	✓	✓																		
89	~~5¾~~	~~CHRISTIENSEN CORE BIT~~																				
90	✓	HTC	OWS	✓			19732	47	9¾													
91	✓	REED	2C	✓			19805	125	25¼													
92	✓	✓	✓	✓			20071	166	33													
93	✓	✓	✓	✓			20188	117	26													
94	✓	✓	✓	✓			20291	103	26½													
95	✓	✓	✓	✓			20415	124	30													
96	✓	✓	✓	✓			20515	100	23½													
97	✓	✓	✓	✓			20579	64	21													
98	✓	✓	✓	✓			20656	77	23													
99	✓	✓	✓	✓			20692	36	14½													
100	5¾	CHRISTIENSEN CORE BIT					20729	37	15													
101	5¾	CHRISTIENSEN CORE BIT					20753	24														
102	✓	✓	✓	✓			20757	4														
103	6	REED	2C	R			20778	21	8													
104	5¾	CORE BIT					20791	13	12													
105	6	REED	2C	R			20814	23	13													
106	✓	✓	✓	✓			20849	35	23													
107	✓	✓	✓	✓			20900	51	27													
108	✓	✓	✓	✓			20956	56	28													
109	✓	✓	✓	✓			20992	36	19½													
110	✓	✓	✓	✓			21018	26	16													
111	✓	✓	✓	✓			21085	67	29													
112	✓	✓	✓	✓			21183	98	36													
113	✓	✓	✓	✓			21234	51	18¼													
114	✓	✓	✓	✓			21253	17	16½													
115	✓	✓	✓	✓			21336	83	30													
116	✓	✓	✓	✓			21407	71	30													
117	✓	✓	✓	✓			21463	56	27½													
118	✓	HTC	W7R	✓			21506	43	19													
119	✓	REED	2C	✓			21605	99	35¾													
120	✓	✓	✓	✓			21703	98	33¾													

* Pump Operation: S - Single; P - Parallel;
** Hydraulic HP Based

Observed Data

Bit no.	Bit Size	Bit Mfgr.	Bit Type	Jet-vj Reg-d	Watercourses No.	Watercourses Size	Depth Out	Footage	Hours Drld.	Feet per Hour	Bit Weight	Table RPM	Mud Wt.	Mud Vis.	D
121	6	REED	2C	R			21806	103	36				18.1	70	
122	✓	✓	✓	✓			21920	116	42						
123	✓	✓	✓	✓			22027	107	36						
124	✓	✓	✓	✓			22127	100	38¼						
125	✓	✓	✓	✓			22249	122	48				18.6	66	
126	✓	✓	✓	✓			22350	101	37				18.6	66	
127	✓	✓	✓	✓			22447	97	37½						
128	✓	✓	✓	✓			22559	112	41¾				Recorded	12-6-	

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ALABAMA

★ Texas operators have spudded in a new wildcat well in Escambia County. This significant well is designated M. B. Rudman et al-Dale Armour Alger-Sullivan No. 1 located approximately three miles south of the town of Lottie and one mile east of the Baldwin County line. Participating in the venture are three Texas operators, M. B. Rudman of Dallas, A. S. Genecov of Tyler, Tri-Mark Oil Company of Corpus Christi and C. Dale Armour of Pensacola, Florida. The venture is being drilled on a Stanolind Oil & Gas Company farm-out to test the Tuscaloosa formation expected to be encountered at a depth of approximately 7000 ft. The similarity of this structure to the Pollard field some 20 miles southeast has aroused considerable interest.

TEXAS

★ A new pool has been opened within the city limits of Liberty, Liberty County. The well is the Kilroy Company T. E. Danziger No. 1, an extreme northwest flanker to the South Liberty field. It has been completed for 77 bbl of 35 deg oil daily on a 12/64-in. choke from 10,034-040 ft.

★ New pay from the Wolfcamp has been found in Ector County by the Felmont Oil Corporation. The wildcat, No. 1 Roy Parks, is seven miles northwest of Odessa, flowed 231.96 bbl of oil per day through 25/64-in. choke on potential tests through perforations at 10,020-052 ft. The new pool opener is three miles north of the Headlee multi-pay field and a mile west of a 11,187 ft Pennsylvanian dry hole.

★ Irion County is holding the interest of West Texans, showing its fourth major strike since the middle of March. A recent discovery is the Murphy Drilling and Production No. 1 Ashe, located four miles north of Barnhart. This well, started by Mark A. Eidelbach, has recorded a major oil flow from the Clearfork section of the Permian. On completion at 4620-40 it tested oil at the rate of 277 bbl daily through 20/64-in. choke. Flow was natural with gas-oil ratio of 800 to 1.

British American Oil Producing Company and Atlantic Refining have confirmed the original Sixty-Seven (Strawn lime) field opener in Irion County with a flowing producer 10 miles southwest of Mertzon. The Noelke No. 2 well flowed 77 bbl of oil in 7 hours following a 500 gal acid wash, through a 24/64-in. choke. Oil is from perforations at 6922-26 ft. This well is a southwest offset to the pool opener. Significant oil and gas shows are being found at various depths ranging from 3475 to 5110 ft in several wells now being tested near Mertzon.

★ Texas American Oil Corporation & Rutter and Wilbanks Brothers No. 2-35 Nunn in Reagan County, flowed 360 bbl of oil per day on official 24 hour potential through a 24/64-in. choke. This well is producing from the Spraberry through perforations from 6382 to 6532 ft after fracture treatment with 21,000 gal. The gravity of the oil was 40.6 deg with a gas-oil ratio of 880 to 1.

OKLAHOMA

★ A significant Bromide sand discovery in McClain County has been made at Gulf Oil Corporation No. 1 Dyer. A second test of the well netted a flow of 146 bbl of oil in two hours from perforations between 10,100 and 10,200 ft through a ½-in. choke. A first test made 117 bbl of oil in four hours through a 14/64-in. choke. Gulf is now testing the Hunton lime at 8950-97 ft.

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What's doing in DRILLING

★ **Atlantic Refining Company** has recently decentralized its drilling functions in the Gulf Coast, West Texas-New Mexico and Oklahoma-Kansas regions. Regional drilling managers have been appointed in each area. The change leaves drilling supervision in the Dallas-Eastern region and the Rocky Mountain region with the general drilling superintendent at Dallas.

★ **First drilling Tender** for Llano Drilling Company, Midland, Texas, has been christened recently in Orange, Texas, shipyards. The firm now operates five rotaries in West Texas and New Mexico. The new vessel, valued at $1,500,000, was christened the Clayton O. Dorn, named for the late Clayton Dorn, founder of Forest Oil Corporation of Bradford, Pennsylvania. The tender measures 54 by 260 ft. and will be used in conjunction with a rig designed for 20,000 ft. drilling.

★ **Company dissolution** of the Graham-Messman-Rinehart drilling and producing firm has been announced. Three new companies have been set up. Roger L. Messman and C. B. Rinehart have established the Messman and Rinehart Drilling Company and the Messman and Rinehart Oil Company with offices in Wichita, Kansas. William L. Graham has purchased three rotary rigs and two cable tool units from the group to set up his own organization.

★ **Primer of Oilwell Drilling** is soon to be updated and revised. The basic reference, published by the American Association of Oilwell Drilling Contractors, has sold more than 50,000 copies since first printed in 1951. Completion of the new project is expected in early 1957 by an AAODC subcommittee headed by Jack Abernathy, Oklahoma City, Oklahoma, in cooperation with John Woodruff of the University of Texas.

★ **Caplen Field,** Galveston County, Texas, will get a try on the seaward side, with a new test to be drilled onshore with an offshore objective. The attempt will be made by Christi, Mitchell & Mitchell, Houston, Texas, operators.

★ **The Texas tale** about the cattleman who strikes oil while hunting water gets older all the time — but it still happens. Roy R. Keith of Leona, Texas, recently drilled a water well on his property with the disappointing result of a three-barrel oil well. Keith claims he doesn't have enough water for household needs. What's worse, this is the second time this has happened to him. The first well went to 363 ft finding nothing but oil.

★ **Turbo drill** development will continue, says H. N. Mallon, president of Dresser Industries, whose company was recently denied permission to enter into an arrangement with the Russian government for a Russian made drill. Mallon stated that "The petroleum industry in the free world is being deprived temporarily of an improved tool for certain types of drilling," but will "cooperate with the Commerce Department in every respect and will abide by its ruling."

★ **A new offshore organization,** the Delta Marine Drilling Company, has been set up, with controlling interest held by Delta Drilling Company, Tyler, Texas. Joe Zeppa, who is president of the new firm, has announced that contracts have been let for conversion of a 326-ft. LST into a drilling tender and for construction of a Hayward-type submersible barge for drilling in 30-ft. water. The company plans to utilize a 2000-hp. diesel electric powered rig in the first unit. A Delta Marine office has been opened in New Orleans, Louisiana.

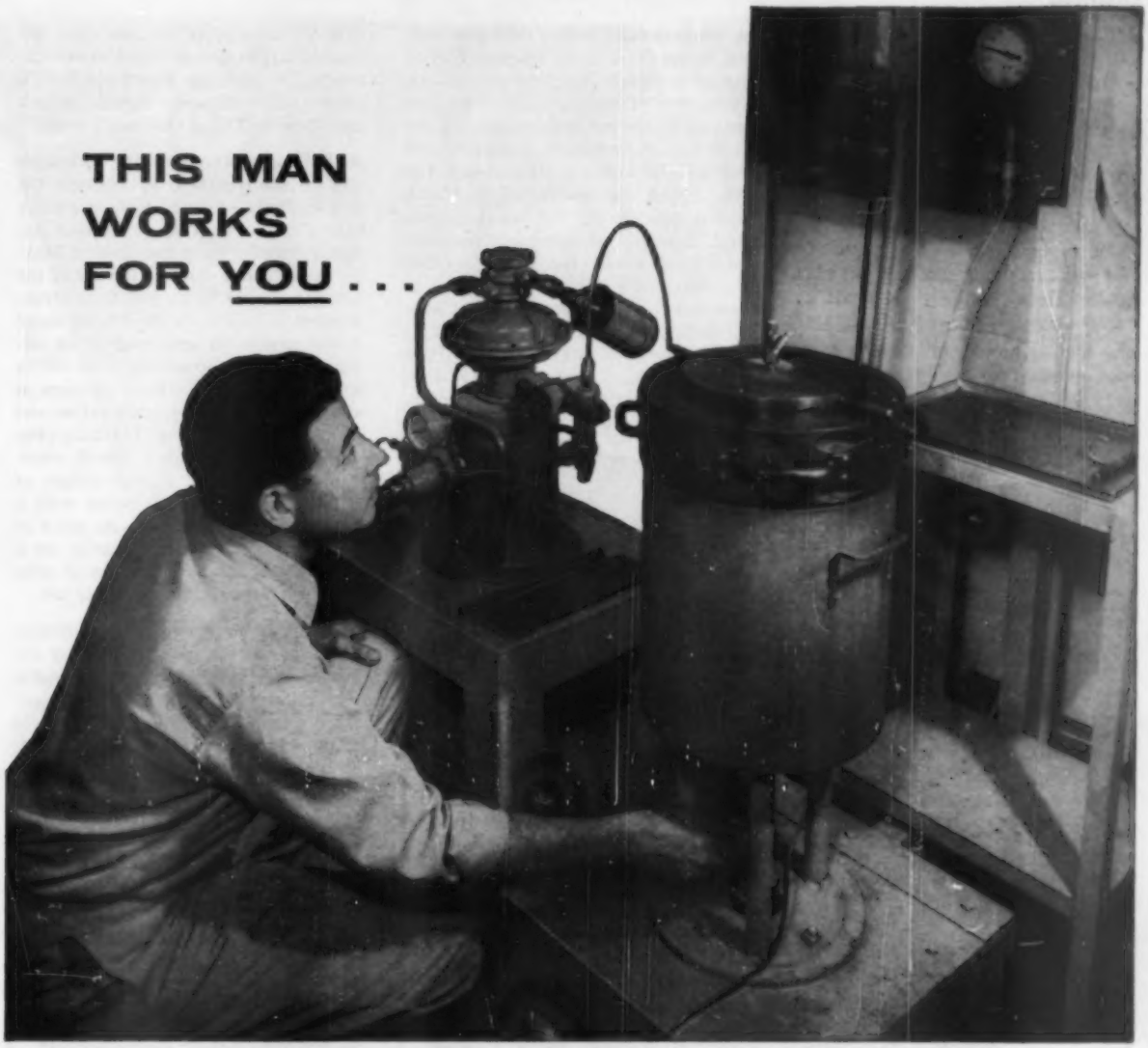
★ **One of the largest gas wells** has been completed in Texas County, Oklahoma, for Panhandle Eastern Pipe Line Company. The well is the No. 2-7 Allender, and is located on the east flank of the Guymon-Hugoton field. On a state test of the Morrow sand, a gas flow of 172,722,000 cu. ft. per day was recorded. Perforations were at 6284-6300 ft. The well had been plugged back and casing set at 6351 ft.

★ **Down in the dumps drilling** near Houston, Texas, is nothing to frown about. Drilling operations in and around the Holmes Road Dump in the Pierce Junction field continues to be successful. Humble Oil and Refining has completed its No. 8 William Rice Fee for 167 bbl of oil through a medium choke from perforations at 7790-7811 ft, as a fine example of the extension work in this area.

Rotary Rigs Operating in Oil Fields of United States and Canada*

	May 7	May 14
Alabama	9	11
Arkansas	15	15
Arizona	0	0
California	129	126
Colorado	57	52
Florida	0	0
Georgia	0	0
Illinois	83	91
Indiana	9	5
Iowa	0	0
Kansas	168	184
Kentucky	11	6
North Louisiana	62	61
South Louisiana	381	374
Total Louisiana	443	435
Maryland	0	0
Michigan	8	9
Missouri	2	2
Montana	40	38
Mississippi	20	23
Nebraska	38	42
Nevada	1	1
New Mexico	143	141
New York	0	0
North Carolina	0	0
North Dakota	21	22
Ohio	2	2
Oklahoma	299	320
Oregon	0	0
Pennsylvania	6	5
South Dakota	0	0
Tennessee	0	0
Texas Gulf Coast	255	264
West Texas	403	424
North Texas	376	393
East Texas	64	62
Total Texas	1098	1143
Utah	15	16
West Virginia	2	3
Wyoming	70	72
United States	2689	2764
Western Canada	137	176
Grand Total	2826	2940

*As reported to the American Association of Oilwell Drilling Contractors by Hughes Tool Company.



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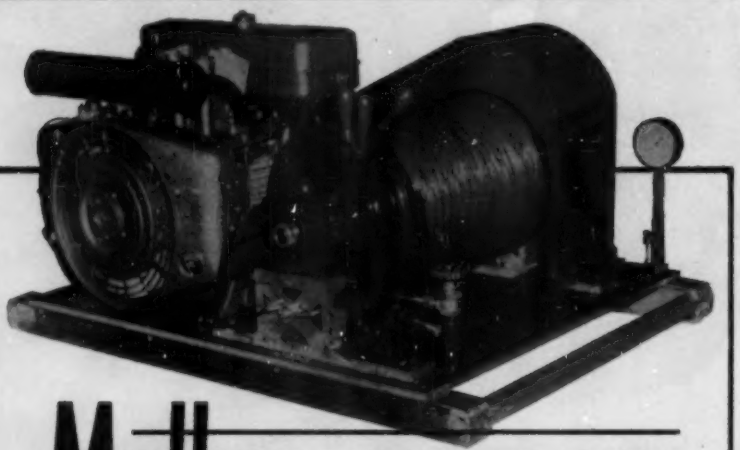
★ **In California,** General Petroleum Corporation has completed its second well, Santa Fe No. 244, in the new deep zone discovery at Santa Fe Springs flowing at the rate of 968 bbl per day net of 32.7 gravity oil. The discovery well, Santa Fe No. 243, was completed last February heralding the first new discovery of any significance in the famous field in many years. No. 244 was completed at a depth of 9020 ft and flowed through a 24/64 in. choke with a pressure of 1100 to 1200 psi. The discovery well has been cut back to a flow of 548 bbl daily through a 22/64-in. choke.

★ **Directionally drilled tidelands well,** the Signal Oil & Gas Company-City of Redondo Beach No. 2 tested between 2900-3040 ft where it indicated a flow rate of 51 bbl per hour cutting 12 per cent mud. A protection string has been run and the well is drilling ahead. The No. 1 well was completed in March and is flowing 183 bbl per day gross of 25.2 gravity oil, cutting 10 per cent, on a ¼-in. choke. Indications are that the No. 2 well may have turned up an extension of the Redondo-Torrance production. The first well is producing from the over-all interval of 2850-3098 ft, and while it appears that the productive intervals of both wells overlap, it is not necessarily the case since the quoted depths do not represent vertical depth. The Redondo Beach project is a joint venture between Signal, Artnell and Reserve Oil & Gas companies.

★ **Drilling platform raising technique** will be demonstrated by Humble Oil and Refining soon. Humble engineers expect to cut the cost of erecting stationary platforms in the Gulf of Mexico considerably through the use of the company's new 90 by 300 ft construction barge. Called the DB-71, the barge is the largest yet comissioned for offshore duty. Its success lies in its ability to handle larger platform sections at sea permitting more prefabrication and reducing erection time. The barge has two cranes, one with a 220-ft boom capable of hoisting a dead weight of 250 tons, and a 115-ft boom with a lifting capacity of 45 tons. As proof of the pudding, the barge recently set a crown block atop a derrick in 25 minutes, usually a four or five hour job.

★ **Drilling in Oregon** is foreseen as Standard Oil of California is expected to begin extensive geological exploration in Marion County soon. The planned operations have been granted in a recent agreement and filed in the county court. This county is the location of Salem, the state capital.



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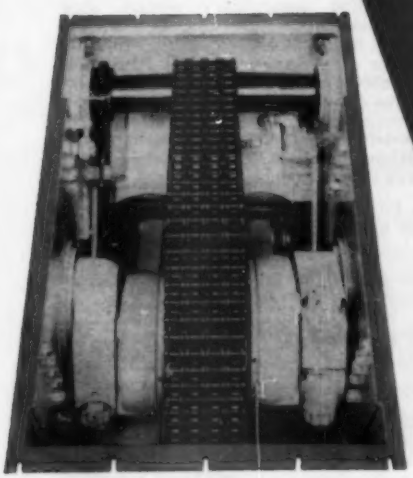

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RUNNING TOUR with MEN in the INDUSTRY

Warren Perry is the new manager of operations for Loffland Brothers Company. He joined Loffland in 1930 and rose to superintendent of the Oklahoma division in 1947, where he is succeeded by **Charles D. Brown,** with Loffland since 1929.

Warren Perry

O. T. Lawhorn

O. T. Lawhorn has been appointed chief geophysicist for the Chicago Corporation. Formerly chief geophysicist for Pan American Producing Company, Lawhorn is a 20-year veteran in this field and will be heading Chicago's geophysical program.

R. M. Carter, district superintendent with Shell Oil Company, has been named to head the company's newly created production district in Abilene, Texas. With Shell since 1946, he will direct production activities in a 43-county area around Abilene.

J. H. Beach and **Victor Church,** formerly with Oceanic Oil Company, have established geological consulting offices in Bakersfield, California.

Jack R. Fraser has been appointed senior petroleum engineer to the Dallas, Texas, engineering staff for Republic Natural Gas Company. **Dan N. Bailey** has been made junior petroleum engineer in the Hugoton district. Fraser was formerly associated with the Shell Oil Company and Texas Eastern Production Company.

James H. Irwin has been appointed vice president of drilling with General Petroleums of Canada, Ltd. Irwin has been with the company since 1942 and has been assistant drilling superintendent in charge of Saskatchewan operations since 1950.

James E. Ubben has been appointed standardization engineer in the American Petroleum Institute's division of production headquarters. He will work with the assistant director in charge of standardization, on a wide range of API equipment and materials standardization projects. Ubben previously was with Emsco Manufacturing Company as chief engineer in the Garland, Texas, plant.

Jack Whitehouse has been appointed to the Shell Oil Company public relations staff in charge of press relations. He is in the Los Angeles office, headquarters of Shell's Pacific Coast area, and replaces **William Hoyt,** now heading Shell's public relations activities in Tulsa, Oklahoma.

Whitehouse has edited a number of weekly newspapers, managing Yuma, Arizona, newspapers, associate editor of Desert Magazine, and most recently as a free-lance agent.

C. L. Clausel, retired president and founder of A-1 Bit & Tool Company, has been named administrative assistant for operations of the Housh Drilling Company, Portable Bridge & Equipment Company, and other Housh interests.

He began his petroleum career in 1919 as roughneck with the J. S. Cullinan Interests. In 1932 he organized the A-1 company, which he directed as president and chairman of the board until his retirement in 1955. Since then he has been an independent oil operator and drilling contractor.

H. O. Heckert, contract representative for Loffland Brothers Company, has been transferred from Midland, Texas, to New Orleans, Louisiana, to be in charge of the New Orleans contract division. Heckert joined Loffland Brothers Company in 1949, and prior to this transfer was in charge of the Midland office.

Guy R. Brainard

Guy R. Brainard Jr. has become associated with Drilling and Exploration Company, Inc., as a vice president. Brainard has been vice president of Lucerne Corporation in Dallas, Texas, since 1951.

A. L. Saulsbury has been promoted to the position of drilling superintendent for the southern division of General Petroleum Corporation. He joined the company in 1916 as a rig builder.

Signal Oil and Gas Company has established offices in Tulsa, Oklahoma, to handle its rapidly expanding operations in the Mid-Continent, naming **Paul Chambers** to represent that department. Chambers comes to Signal after gaining wide experience in technical and contract phases of the natural gas and gasoline business.

Paul Chambers

T. B. Houck, drilling superintendent for Parker Drilling Company, has been named acting manager of Pantepec Oil Company in Tel Aviv, Israel, whose drilling and production will be managed by Parker.

Howard D. Henderson, manager of the Gulf Coast division, Sohio Petroleum Company, has been appointed to the newly-created post as co-ordinator of foreign operations. He also will assist the vice presidents' assistant in charge of explorations.

Claude W. Bard has been promoted from general drilling superintendent to general manager by the Garvey Drilling Company. Bard has been active in the drilling industry for the past twenty-five years, joining Garvey in 1948.

John H. Wents Jr., has been named assistant general manager of Tidewater Oil Company's central division, with headquarters in Tulsa, Oklahoma. Succeeding **Charles R. Brown,** recently advanced to general manager of the central division, Wents transfers to Tulsa from Tidewater's western division.

Russell Farmer has resigned from the U. S. Smelting, Mining & Refining Company to become chief geologist for Hill and Hill, independent operators in Fort Worth, Texas.

James W. Water, chief engineer for Ambassador Oil Company, Fort Worth, Texas, has been transferred to Oklahoma City, Oklahoma, as production superintendent.

J. D. Christner, succeeds Water in Fort Worth, after resigning as senior petroleum engineer for Stanolind Oil and Gas Company, which he served for 15 years.

M. E. Witherspoon, formerly assistant to the vice president for Plymouth Oil Company, at Sinton, Texas, has been transferred to Midland, Texas and promoted to regional supervisor in charge of all activities in West Texas and eastern New Mexico.

Associated with Plymouth since 1927, he was appointed assistant to vice president in 1954.

A reassignment of production department supervisory duties for Sunray Mid-Continent Oil Company has been announced. **V. L. (Fred) Smith,** Oklahoma City, formerly Oklahoma district superintendent, has been named district superintendent of the North and West Texas district, Midland, Texas. **J. F. (Duke) Dingee,** Great Bend, Kansas, formerly assistant superintendent for the Kansas district, succeeds Smith at Oklahoma City. **E. F. Patrick,** formerly at Midland, has been named superintendent of the production department's western area operations.

R. R. Rothrock, formerly Sunray's Osage area superintendent in Pawhuska, Oklahoma, has been transferred to Oklahoma City as assistant Oklahoma district superintendent. **L. A. Prichett,** formerly western area field superintendent in the Oklahoma district, has been named Osage area superintendent at Pawhuska.

Ed Peterson Jr., North Texas oil operator and partner in the oil operating and producing firm of Peterson and McCarty, has been named director of the Seaboard Oil and Gas Company of Wichita Falls, Texas. He has had approximately 20 years experience in the oil business which he first entered as a roughneck and roustabout.

Ed Peterson Jr.

F. H. Clements has been named field superintendent at Stanolind Oil and Gas Company's Yates area at Iraan, Texas. He replaces **E. J. Harmon,** who is retiring. With Stanolind since 1946, Clements was a production foreman prior to this promotion.

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McCullough Back-Off Service Aids in Recovery of an Extra 3600′ of Stuck Pipe

In some stuck pipe conditions McCullough's Magna-Tector (Free Point Finder) will indicate that working the pipe may free it further down the hole. In this instance the stuck drill pipe was actually loosened 3,600′ below the original sticking point.

Operator was drilling at 5,668′ with 3½″ Full Hole Drill Pipe when pipe stuck. This was a 32° angle directional well.

McCullough was called to run their combination Magna-Tector, String Shot Back-Off. Lowest free point was found at 1,900′. However, the Magna-Tector reading indicated that the drill pipe might be freed further down the hole.

Pipe was worked for 2½ hours and the combination Magna-Tector, String Shot Back-Off was again run. Pipe was found to be free at 5,500′ at the top of the drill collars. The String Shot Back-Off was positioned and fired and pipe was recovered from that point—a bonus of 3,600′ of drill pipe.

McCullough's new combination "One Trip" Back-Off Service obtained the free point reading and fired the back-off shot on a single trip in the hole. Thus, all free pipe was backed off and started out of the well almost immediately after the lowest free point had been found—and before it had a chance to re-stick further back up the hole.

Magna-Tector Helps Save 12 Days Fishing Time on Stuck Pipe Job

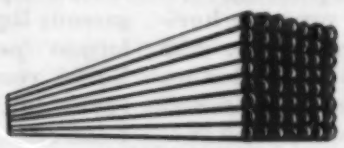
Operator Estimated 21 Days to recover 7760′ of Stuck Drill Pipe—Job Actually Completed in 9 Days with Aid of McCullough Back-Off Service.

The time-saving benefits of McCullough Back-Off Service in pipe recovery operations were strikingly demonstrated in this deep California well.

Operator was drilling at 11,360′ when 4½″ O.D. drill pipe became stuck. Only surface casing had been set and hole was open from 500′ to 11,360′.

McCullough was called immediately. The Magna-Tector (Free Point Finder) located the lowest free point in the stuck string at 3,600′. A String Shot Back-Off was fired at that point and the free pipe was removed from the hole.

At the time of the first back-off the Drilling Superintendent advised his head office that it would require an estimated 22 washover operations, 22 String Shot Back-Off shots and 21 days of rig time to recover the remaining 7,760′ of stuck drill pipe. However, due to reliable free point determination, the job was completed in only nine days. After each washover operation, McCullough's Magna-Tector was run to confirm that the washed-over pipe was free. In each instance the Magna-Tector discovered that pipe was free a considerable distance below the lowest washover point. McCullough's String Shot Back-Off successfully loosened the lowest free joint in every case and permitted fast recovery of the freed sections.



Call for—McCULLOUGH BACK-OFF SERVICE

McCullough "One Trip" Back-Off Service is now available in most service areas—performs all back-off operations in one electric wire line run in the hole—ask your McCullough Service Engineer.

Instead of 22 separate washover and back-off operations, the use of McCullough Back-Off Service enabled completion of the job in only four recovery operations.

Count the savings this operator made through his foresight in calling for McCullough Back-Off Service. Saved—18 String Shot Back-Off shots—18 separate washover operations—12 days rig time.

It pays to call for McCullough Back-Off Service. You'll save time—save pipe—save money!

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Two-stage separation is a perfect example of the advantages offered by Parkersburg single tube horizontal separators.

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Easy to install, these units have all the outstanding performance features of Parkersburg's famous horizontal separators: 20% greater interface area for de-gassing; 20% slower gas flow for more effective natural separation; longer retention of more gaseous liquids; incoming fluid broken into largest possible droplets; all entrained liquid removed from gas stream; liquid level maintained by No-Bleed Level Controller.

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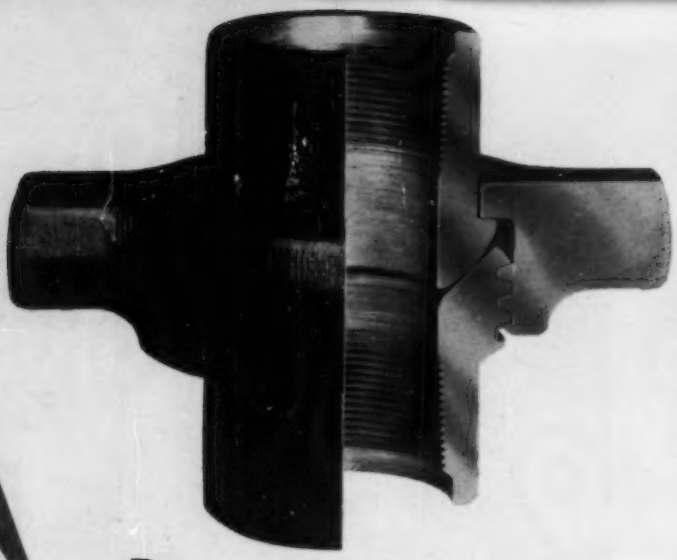

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Way ahead in dependability — *The famous ball and cone seat forms a positive metal-to-metal seal you can always depend on for a leak-proof seal.*

Way ahead in service — *WECO's tough wing nut, rugged Acme threads, and heavier wall sections are built to take rough treatment . . . to serve you month after month — on job after job.*

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Way ahead in availability — *You'll find WECO Unions at supply stores in all active oil producing areas — ready to do a better job — longer.*

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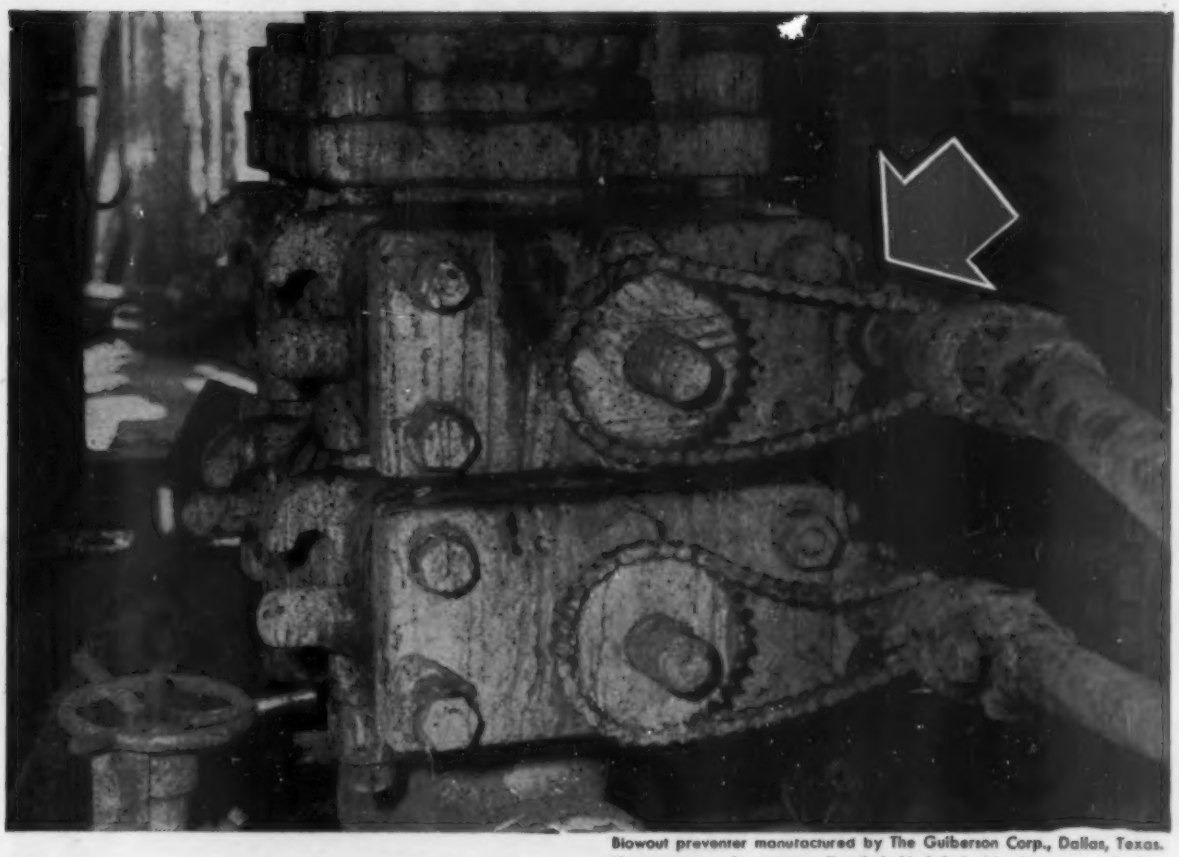

Blowout preventer manufactured by The Guiberson Corp., Dallas, Texas. Neoprene ram elements are directly behind chain drive in preventer body.

"When you're drilling in high-pressure areas, you can depend on blowout preventers with *NEOPRENE* ram elements"

says Cliff Braswell of Associated Oil Field Rentals, Odessa, Texas

"In West Texas they drill a lot of holes in high-pressure areas. A driller can never tell when a well's going to 'kick,' so he's got to be ready all the time—and his equipment's got to keep coming through in the pinches. That's why we rent blowout preventers with neoprene ram elements. We know from experience that neoprene can really take it.

"Like the time in the Permian Basin. They had drilled into the sand and knew they'd hit pay. In coming out of the hole she began to kick. They closed the blowout preventer and she stopped cold—those neoprene ram rubbers really held! After that, it was no trouble to pump in the mud, equalize the pressure and finish the job."

That's Cliff Braswell's experience with neoprene blowout-preventer rubbers—just one of the many products doing a better job in the oil fields because of neoprene. So when you're buying blowout-preventer rubbers, gland packing, mud suction hose, piston rubbers or gaskets, be sure to specify NEOPRENE.

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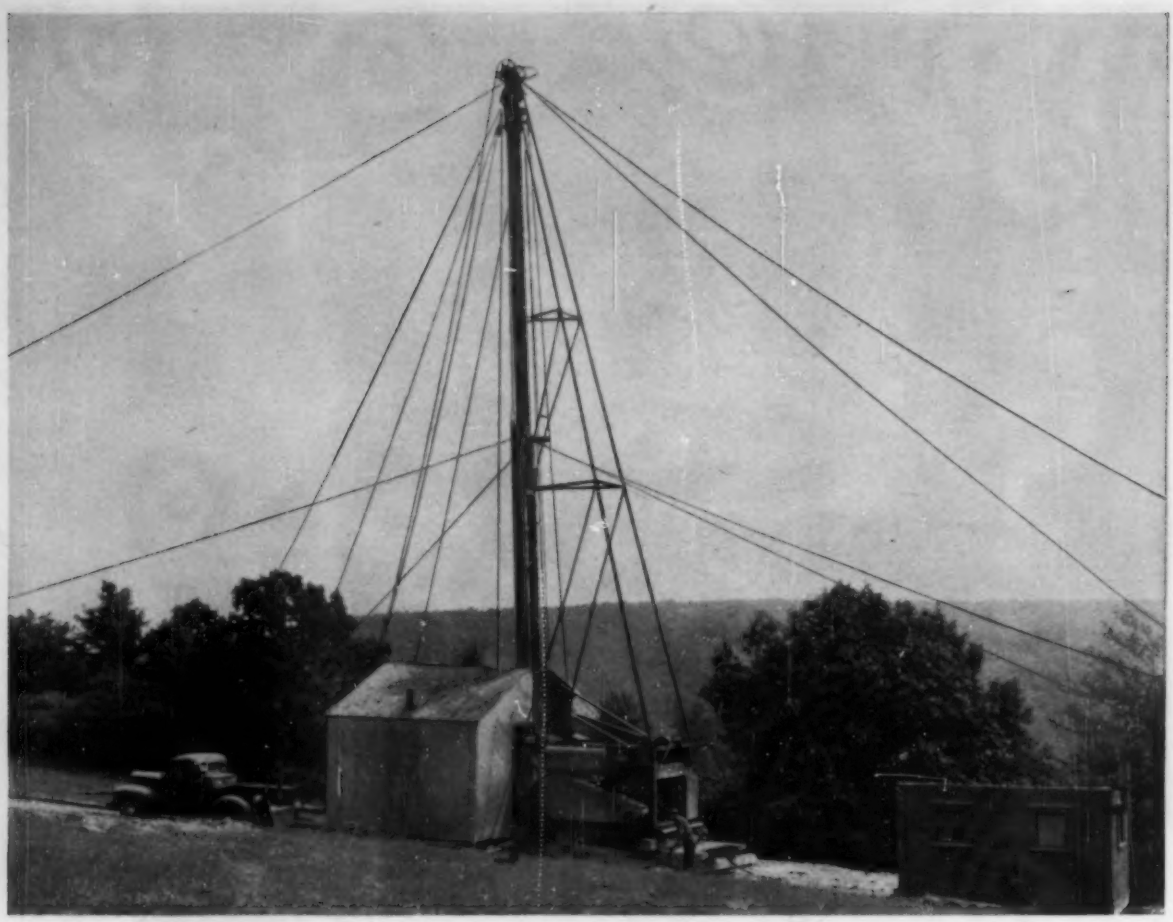

Why BUCYRUS-ERIE Spudders pay off on Secondary Recovery

Bucyrus-Erie spudders offer the speed and mobility you need for fast, profitable secondary recovery operations. These modern rigs assure rapid progress hole after hole, with quick easy moves and reduced costs all down the line.

You can't beat the *speed* with which Bucyrus-Eries put down hole. Snappy spudding action, with shock absorber that can be blocked out for deep drilling, means real drilling speed in any formation. Forward and reverse speeds on all reels and on the catheads provide the accurate, split-second control that diversified operations require. Reels are free-wheeling for lowering. Fast powerful line pulls result in fast trips in handling tools, bailer, casing, or rods in clean-out work.

And when it comes to moves, Bucyrus-Eries really save time. Their telescoping derricks are lowered and raised quickly under power, tubular braces unfold smoothly. Mobile semi-trailers or skid mountings make *moving* easy.

Two popular choices for secondary recovery work are the 60-L and 28-L machines. For complete information on them, see the Bucyrus-Erie spudder distributor in your area or write us direct. 30556

60-L Top-to-bottom drilling to 1,500 ft.; Servicing to 2,000 ft.; Swings up to 2,750 lbs. of tools.

28-L Top-to-bottom drilling to 2,500 ft.; Servicing to 3,000 ft.; Swings up to 3,700 lbs. of tools.

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for every pumping condition

D+B SUCKER RODS

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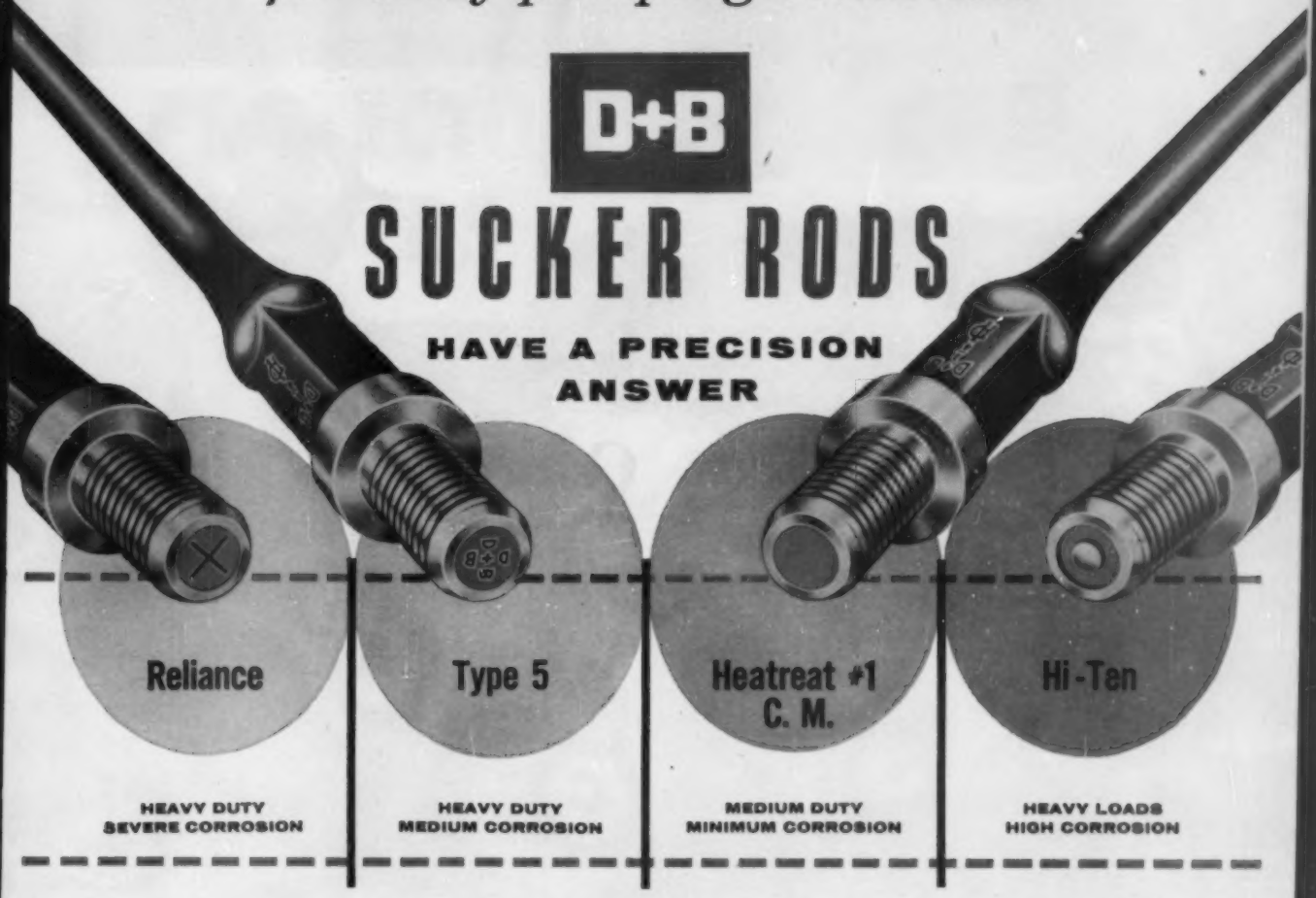

To give you the right combination of strength, ductility, hardness and impact properties, D+B Sucker Rods are made from metallurgically controlled steel, full length heat-treated under accurate factory conditions. Carefully controlled straightening, forging, full length normalizing and drawing, shot blasting, threading and painting operations assure long, trouble free service in the well. Stop in or call today at your nearest CONTINENTAL or D+B store and select from complete stocks.

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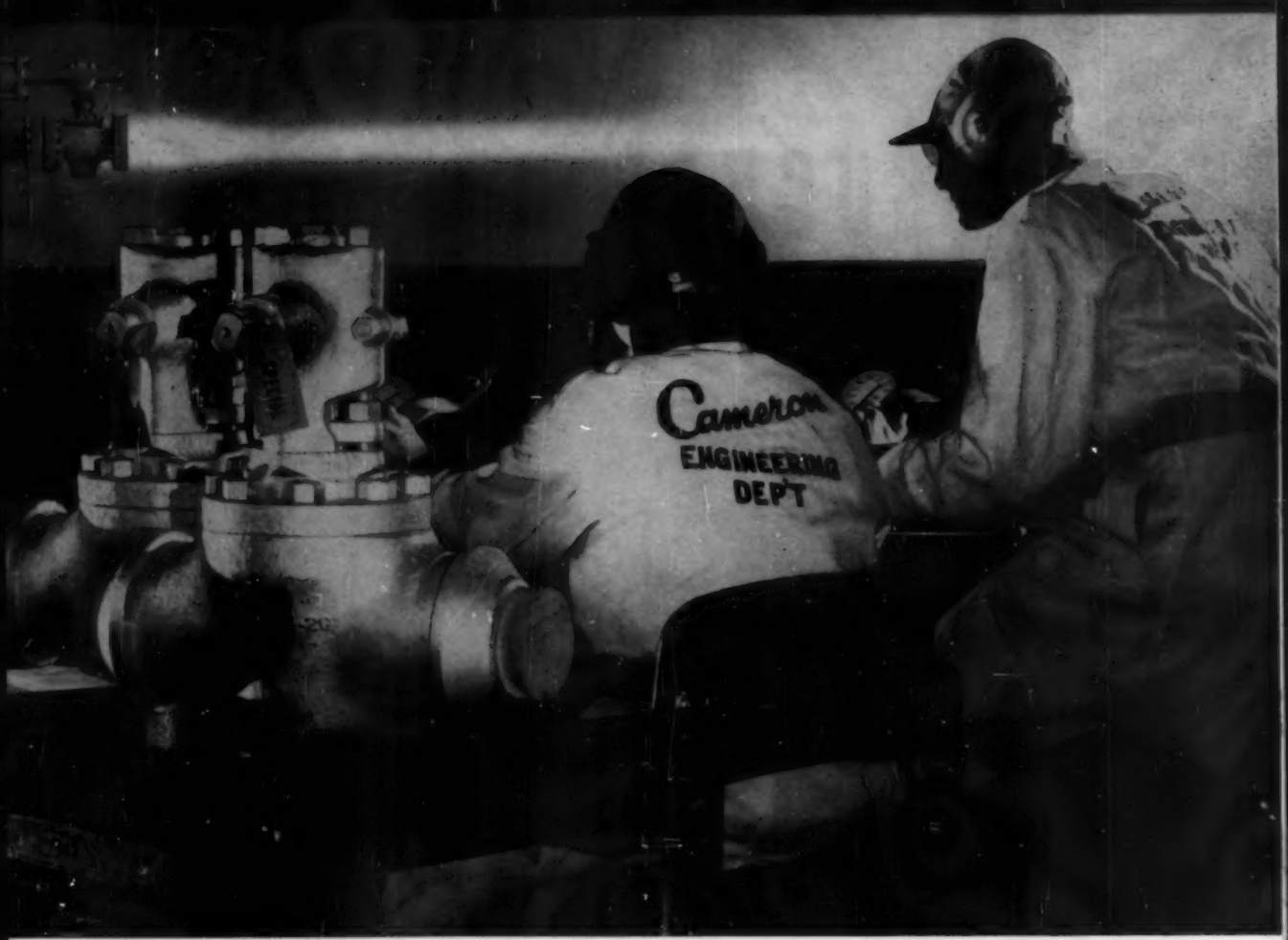

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Control of liquids and gases has been a classic problem to designers for endless ages. Never before, however, have valves been called upon to control such a variety of difficult materials under such extreme conditions. Problems of our age present a challenge which has produced radical improvements in valve design.

Here at Cameron the remarkable Non-Lubricated Lift-Plug Valve is working ranges of pressure, volume and time which produce controlled "explosions." These high speed operating cycles simulate actual operating conditions to which our valves are subjected in service applications today.

The versatile Cameron Lift-Plug Valve is replacing more and more ordinary valves in many difficult services. Temperatures to 1600°F., corrosive acids, slurries, LPG and even beverages and foods are among the many applications in which these valves have had outstanding records for a number of years. You may not need to control an "explosion" in your processes but most likely you have a place where the Cameron Non-Lubricated Lift-Plug Valve can save time and money.

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Stay Put.. Keep Their Grip.. Keep Their Size..

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You get extra casing protection and extra performance from Guiberson protector rubbers because they're made from a special wear-resisting rubber compound, designed for universal application in all kinds of drilling. And you get it because Guiberson just plain *knows how* to mold and compound rubber products that can take the tough jobs in today's wells— and lick them.

That extra rubber know-how comes from Guiberson's long years of experience in manufacturing rubber products specifically for the oil industry. It comes from a rubber plant and laboratory staffed and equipped to do the specialized job right. When you want drill pipe protectors that won't walk and do maintain their original OD for a long, useful life, look to Guiberson for the answer.

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PUMPING ENGINES

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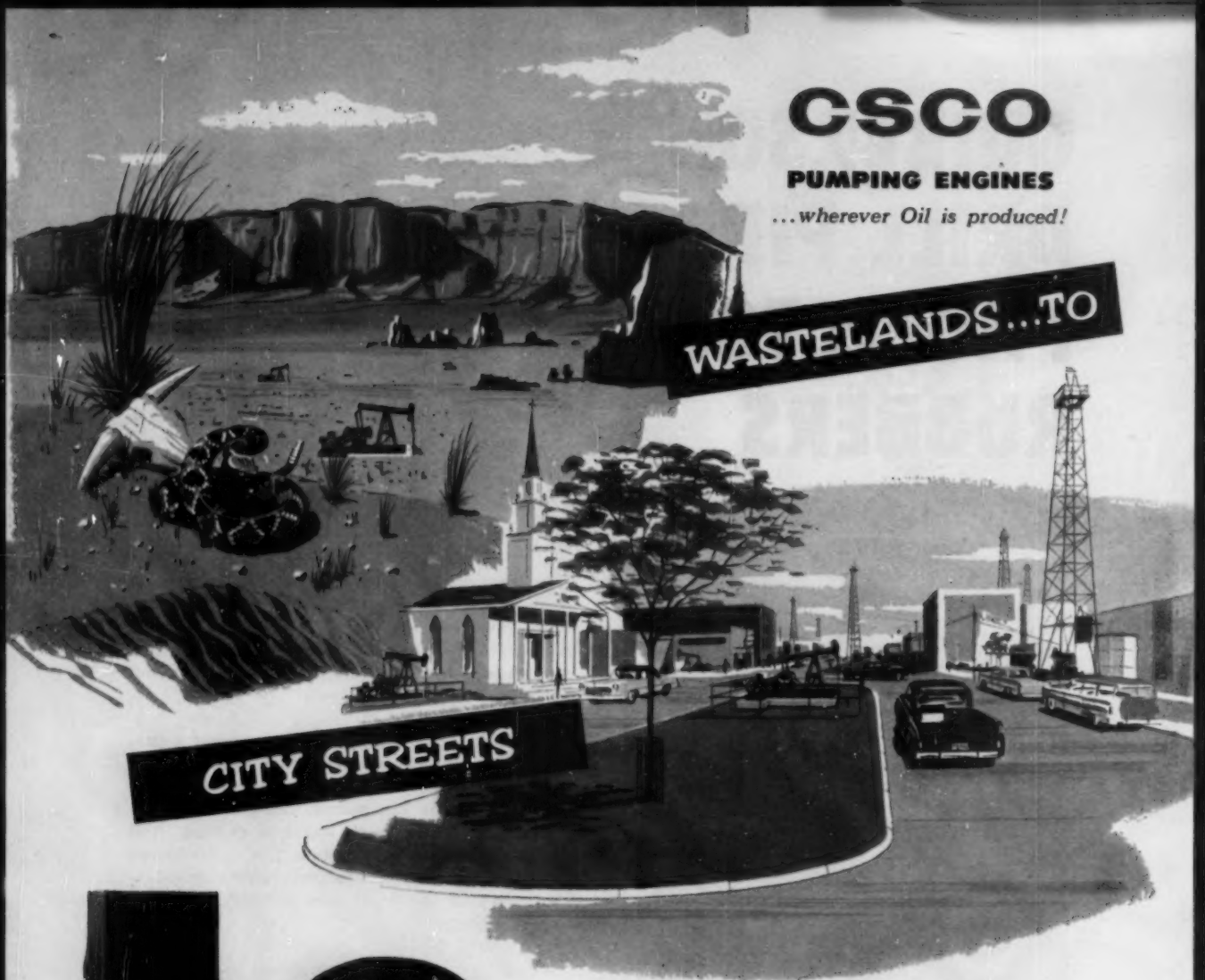

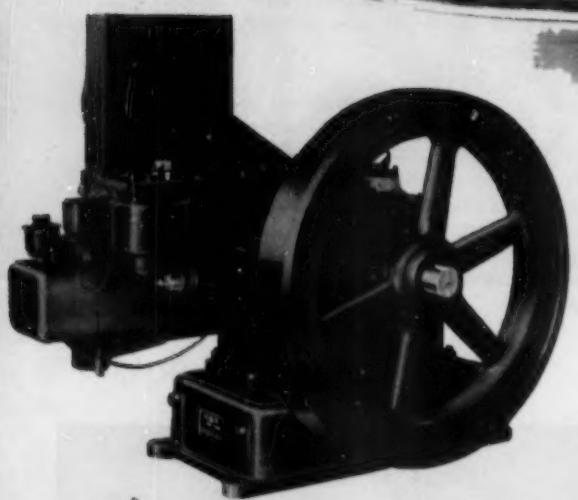

Whether Operating in Isolated or Crowded Areas—Under All Conditions—CSCO Pumping Engines are Easiest to Maintain

Only CSCO Engines have ALL 4 of these important features:

EASY TO REPAIR . . . CSCO parts needing repair or attention can be removed from the engine with a minimum of disturbance of adjacent parts or assemblies. The reason: CSCO exclusive design embodies unit assemblies permitting quick and easy accessibility. For example, the piston and rod assembly is easily removed through the crankcase without draining the water or oil. No other essential parts are disturbed!

EASY TO SERVICE . . . There's no need to stop a CSCO to check oil level . . . to add oil . . . to check water level . . . or to add water. And you can SEE when an oil change is needed, for on a CSCO the oil level is plainly visible at all times. Instant wrenchless access to the crankcase, through the extra large opening, makes oil changing and cleaning out of the oil sump easy and quick. Since there's no need to stop, there's no need to restart!

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Heat Transfer Equipment Needs Kellogg's

BUILT-IN ENGINEER

WHEN a process plant's efficiency, and even its economic success, depends on the performance of heat exchangers, this vital equipment becomes more than a "packaged" item or even a matter of following specifications. Optimum performance, at minimum cost to the customer, demands all of the extra know-how, know-when, and know-where that the fabricator can put into the job. It requires, for example, a thorough knowledge of heat transfer, stress analysis, metal fatigue, corrosion control, metallurgy, and welding techniques, plus the inherent ability to apply this knowledge to the specific problem at hand.

At M. W. Kellogg, the instinctive application of this kind of knowledge—which goes into the design and fabrication of every Kellogg heat exchanger or other processing unit, is what we call the "built-in engineer". This important extra, together with Kellogg's other facilities guarantees performance, minimizes maintenance, and often reduces initial costs. In one recent instance, a saving of $5,000 for a customer resulted from a slight change in design suggested by Kellogg's staff.

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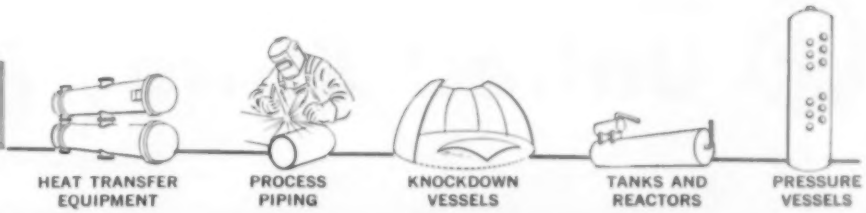
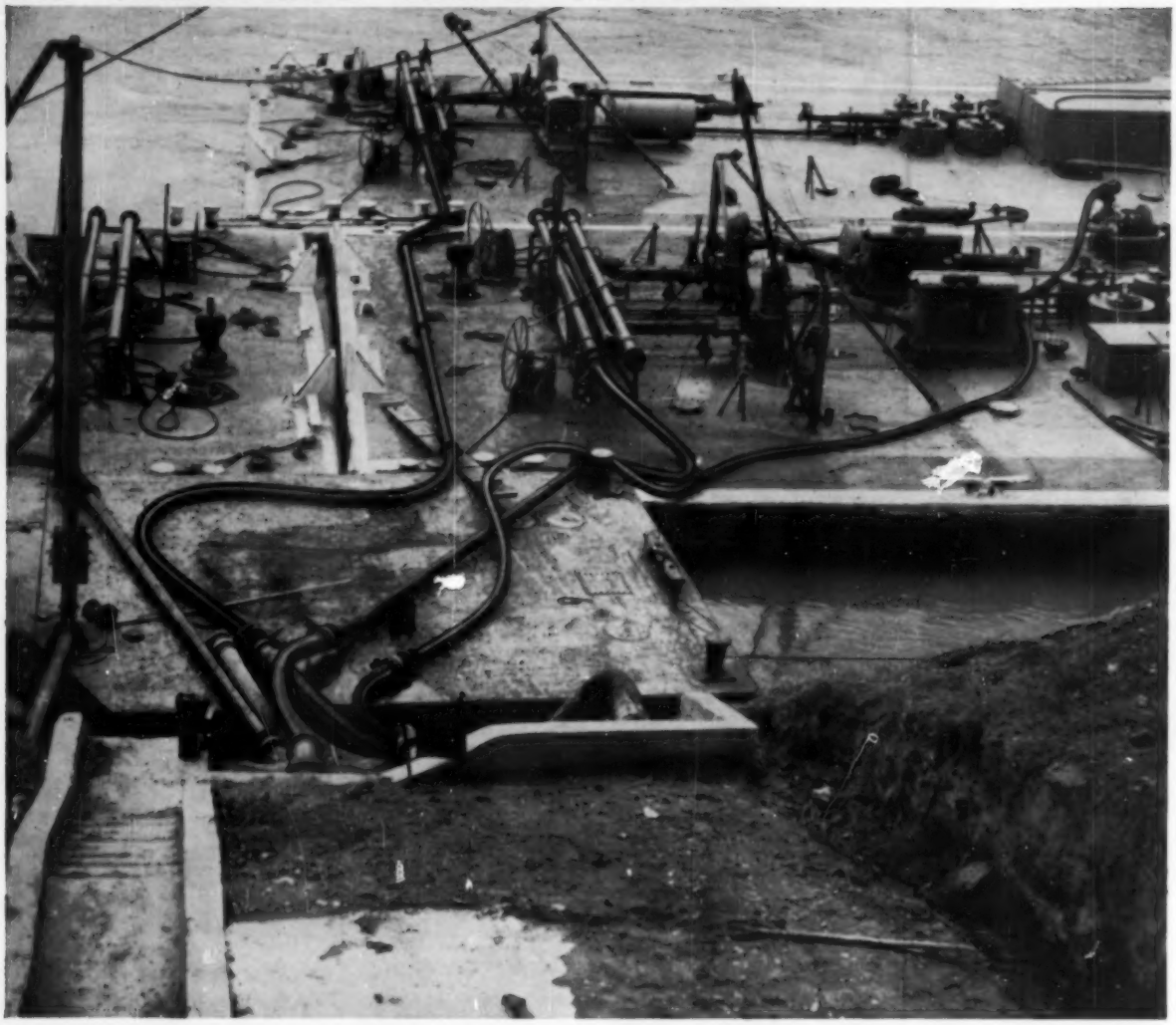


No lifting devices needed to handle this hose—



it's the lightweight U. S. H-1515

This photo ably demonstrates the flexibility of H-1515 for barge hook-ups. The workmen demonstrated its lightness by making the hook-ups *without* using hoists. For this United States Rubber Company hose is 2/3 lighter than ordinary oil-discharge hose. It is so easy to handle that it sharply reduces make-up time—and in turn cuts dock charges. Its light weight has an added plus—*it sharply reduces accident hazards.*

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How Many 'Custombuilt' Motor Fuels?

Into how many divisions or brackets shall the wide octane number band of fuels, required by all the motor car engines in use, be divided? How many grades of gasoline must the fuel marketer keep on hand, to hold and increase his sales? Not a refiner or marketer anywhere but what is studying that $????.?? question now, from every angle he can discover — economics, manufacturing, distribution, crude-to-product division — and none have any final answer, even for a short future period.

In the "more abundant life" (?) of the depression-ridden '30's third grade gasoline, lower in octane number than the other two grades then sold, was introduced to get rid of low-grade stuff that wouldn't sell otherwise, to impoverished buyers who wouldn't buy otherwise. Apparently the chief advantage of this step was to empty the low-grade naphtha tanks in the refinery to permit running more crude — to fill the same tanks again — and to supply other petroleum products needed by the country's stagnating economy.

Now the expansion is on the other end of the octane scale. Pressure of competition in the refinery and the automobile engine factory has forced compression ratios up from a pre-war level of 6.5 or so, to more than 8-to-1, with corresponding increase in octane number needs. Now, some of the highest compression ratio engines being sold in 1954-57 cars need 100 or higher octane rating fuels to avoid the supposedly worrisome ping in the deluxe engine of today. At the start of World War II only aviation engines used that kind of fuel, and then only for fighting purposes. Eddie Rickenbacker won his spurs in World War I flying a Spad using 75 octane number fuel, or lower.

The Bombshell in the Marketplace was the announcement early this year by Sun Oil that it was starting eleven stations in Florida to selling five grades of gasoline from a single pump each, with a proportioning setup that offers choice of a spread of octane ratings from Blue Sunoco, well in the 90's 'tis said, to above 100 octane rating for fuel No. 5 at the top of the scale. The motorist can choose his grade, and a price differential is maintained between these grades. More recently Sun announces extension of the practice to all its Florida stations. While this is not tacit approval by that company of the idea, it does indicate that preliminary results warrant extension to see how the idea takes hold among a greater group of motorists.

Then early in May Esso Standard Oil announced that it will add a super-grade of motor fuel to its marketing pack, to serve better those high compression ratio engines that need more anti-knock than even present premium grade. This new fuel Esso calls Golden Esso. With one out of five present engines on the road calling for more antiknock quality, even with our average premium rating being 96 Research now over the country, there appears to be a real gap in the picture that fuels of 100 or above will fill.

So the gauntlet has been thrown down to other gasoline purveyors, large and small, to toss in their cards or cover the bet set by these two companies. Additional octane numbers must come from more cat cracking and reforming; more alkylation, polymerization, isomerization, more segregation and concentration of high octane number components from the fractions available to the refinery. Tetraethyllead will help boost the rating some of course, will add to the last few numbers more cheaply than any other method.

Strangely, Sun and Esso are nearly at opposite ends of the special refining capacity range that will supply these additional octane numbers. Esso has cat cracking capacity equal to about 50 per cent of its crude capacity; cat reforming is only 5½ per cent of its crude capacity, to be twice that before year's end with new construction. Sun Oil has nearly 60 per cent as much cat cracking capacity as crude facilities, 20 per cent as much cat reforming, the means by which it has gone on for so much of its business history without TEL and is still competing on octane rating. Shell Oil at Wood River has cat cracking equal to only 32 per cent of its crude capacity but 15 per cent cat reforming capacity; include Shell's Houston and Norco refineries and the total cat cracking capacity is 40 per cent of total crude, but only about 8 per cent of cat reforming capacity. Humble Oil & Refining Company, Esso affiliate, has at Baytown cat cracking amounting to one-third (34 per cent) of its crude capacity, 13 per cent cat reforming capacity. Among the smaller refineries a wide divergence of cat treating capacities exist; some have little possibility of competing in the high bracket fuel race and would be forced to supply the lower two grades. Others, notably Cosden Petroleum Corp., merged recently with W. R. Grace Company, wide-ranging chemical concern, are better fitted with cat capacity. Cosden has 47 per cent of its crude capacity in cat cracking, 15 per cent in cat reforming, much of which it uses to produce petrochemical intermediates and specialties but conceivably could apply the products entirely to motor and aviation fuel blending.

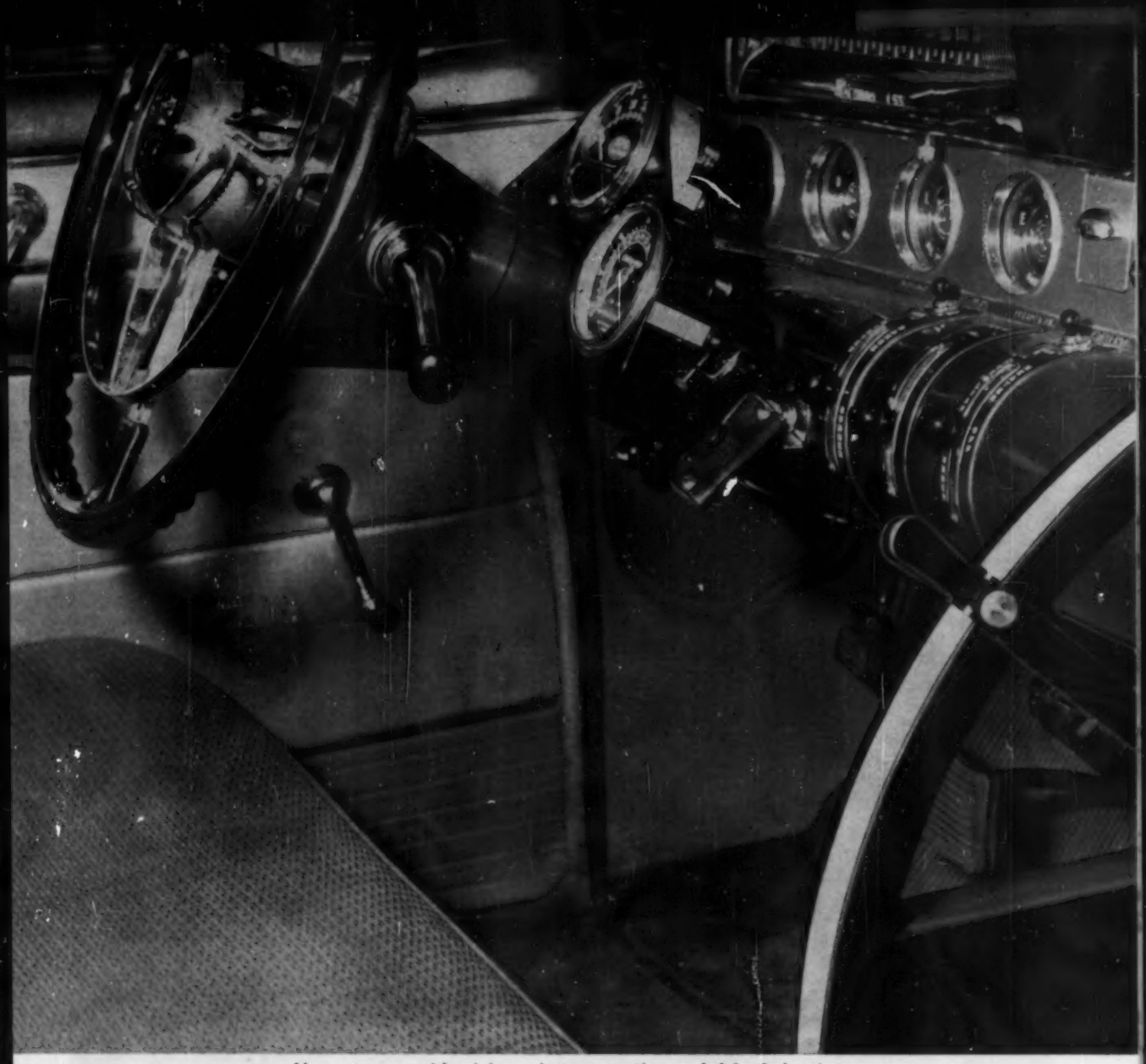
The industry as a whole had at the beginning of 1956 more than 250,000 bbl per day of alkylation capacity, with enough building and planned to crowd the 300,000 bbl per day figure, possibly. Catalytic polymerization, which competes for olefins with alkylation, synthetic rubber and plastics intermediates, showed 140,000 bbl per day capacity, and hydrogenation, mostly desulfurization with some middle distillate upgrading, is reported as more than 430,000 bbl per day. Alkylation and polymerization both are mere "drops in the bucket", nation-wide, as compared to more than 900,000 bbl per day for cat reforming and more than 3,700,000 bbl per day in cat cracking units. Cat reforming will increase its capacity more in 1956 than will any special refining process. Also, this situation explains with obvious logic, it seems, the reason why alkylation plant construction will continue to an indefinite increase in the next few years despite the stoppage of ODM's issuance of rapid tax writeoff certificates. Apparently it is a question, not of "Will all these Units Pay?", but "Can we stay in business without them?"

The new processes, such as UOP's Penex and Atlantic's Pentafining, to isomerize pentanes to obtain higher octane ratings from this important volatile blending agent, may be most timely as another line of attack on the octane-boosting problem.

Careful estimates have been made that, with the main blending component of an octane rating between 95 and 100 (97) Research a refiner, or the whole industry can supply a regular grade at 92, a so-called premium at 98 and a super-dooper fuel at 104 octane number! Higher values have been estimated, but of course the higher the figure the lower the profit chance.

Whether the new ideas of extra-rating, extra-priced fuels will catch on with the public remains to be seen; Esso will try it in the high-octane-demanding East; Sun has expanded its experiment to all of its Florida stations. Every refiner is watching developments with eagle eyes, ready to shift with the signals. Some are merchandising more carefully their existing grades. Esso even claims that the three-grade system will cost for additional refining facilities for the industry a mere half of the $3 billion that will be required to meet the octane number raises of a two-grade system during the next five years. Of course in addition to these costs the additional pumps, stations and marketing facilities will cost a substantial sum.

Arch L. Foster.



Above, test car with minimum instrumentation needed for fuel rating.

How Ethyl Research equips a car for accurate fuel ratings

Ethyl Research has for years been active in developing more accurate and economical ways of obtaining fuel ratings on the road—offering refiners convenient methods for evaluating their gasoline stocks.

At Ethyl Laboratories, we have found that the various road rating procedures can be adequately handled by a grouping of just five instruments, some of which can be seen in the picture above. But we have discovered that the addition of other key equipment (see right-hand page) can facilitate your road testing operations.

Our people have accumulated hundreds of thousands of miles of road testing experience with this equipment. If you would like more

Right, equipment suggested for more complete test-car setup.

information about this subject, please contact your Ethyl technical representative.

INSTRUMENTS SHOWN in this advertisement have proved satisfactory in Ethyl test cars but are not necessarily endorsed by Ethyl Corporation. Although the products of some specific manufacturers are shown, several of the instruments are made by various companies, and we'd be glad to mail you a list of sources. Just send your request to Box 22 Ethyl Corporation, 100 Park Avenue, New York, N.Y.

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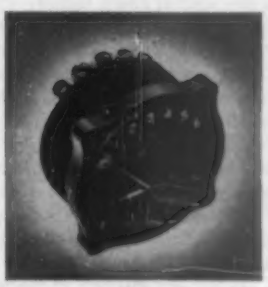
Electronic spark protractor provides an accurate method for continuous indication of spark advance. It gives direct readings at all speeds.

Timing light (above), calibrated flywheel and sight tube are used for obtaining instantaneous spark advance position. Flywheel is marked in crankshaft degrees.

Auxiliary fuel system facilitates testing of several fuels in succession. Simple coupling connects the auxiliary line to the inlet side of the fuel pump.

Tachometers are accurate mechanisms for measuring the engine speed. They are adaptable for operation with any six- or twelve-volt system.

Vacuum gauge is required for part-throttle ratings. At any given car speed, the vacuum gauge permits reproducing part-load conditions.



Selector switches for thermocouples and resistance bulb thermometers are needed to permit reading temperatures at various locations.

Thermocouples and resistance bulbs are used to measure the temperatures of the coolant, the lubricating oil, and the air entering the carburetor.

Potentiometer is used to indicate the temperatures measured by the thermocouples. Road ratings require a rugged instrument, insensitive to vibration.

P 721.33

Revised flow reduces coke deposition, destructive secondary cracking; more gasoline produced, greater flexibility attained

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Shell Oil Company

ABSTRACT

New techniques have been developed in fluid catalytic cracking to provide higher gasoline and lower coke yields and greater flexibility than conventional operation. Attention has been directed to reaction, stripping, and regeneration. Process development has ranged from laboratory experiments through pilot plant development and full plant scale engineering studies at Shell Oil's new refinery at Anacortes, Washington.

Techniques for improving yields and selectivity in commercial fluid catalytic cracking have heretofore been limited to three types, all of which were recognized in the early conceptions of the process. Recycle of gas oil has been an important tool for improving selectivity.[1, 2, 15] High-temperature cracking[1] reduces coke yield but also reduces gasoline and increases gas make and has, therefore, been useful only in a few special cases, usually where large quantities of olefins are desired from a relatively high coke-making feed. Lastly, segregation of feed stocks[17] permits cracking each one under conditions more closely approaching optimum than would be possible if the stocks were admixed. This advantage arises from the marked variations in refractoriness found for hydrocarbons of differing molecular weight and molecular type. [7, 8]

When any mixture of feeds (or even a single feed), having a wide boiling range and a variety of molecular types, is cracked, a compromise severity is required at which the least refractory components are cracked too severely and yield large amounts of gas and coke while other, more refractory components undergo only low conversion. Both overcracking and undercracking prevent realization of optimum potential gasoline yields. While feed stock segregation lessens this shortcoming, it is practical only where several units and/or extensive storage facilities are available.

Even with feed stock segregation, the boiling range and molecular-type spread of a typical catalytic cracking feed stock are so wide that the operating severity required to achieve a given overall conversion inevitably results in some destruction of the gasoline initially produced from the least refractory components. This shortcoming is intensified by the wide distribution of vapor residence times which is found in the fluid beds of conventional catalytic cracking units,[3, 5, 6, 14] and which would lead to overcracking/undercracking losses even with a feed of uniform composition and narrow boiling range.

To minimize these overcracking/undercracking losses, uniform oil/catalyst-contact time is desirable. Moreover, this contact time should be short to avoid secondary reactions of the gasoline produced from the least refractory feed components. Under such conditions, high-temperature operation is desirable since the coke reduction obtained is not accompanied by the usual loss in gasoline yield ascribed to secondary reactions. All of these considerations can be met by carrying out the initial cracking step in a short-contact-time riser reactor, operated at high temperature. Further benefits can be gained from use of a second (and possibly more) reaction stage to which unconverted material from the preceding stage is fed.

The Shell two-stage catalytic cracking process was developed to combine the advantages of short-contact-time cracking and of multiple staging. Their use in finished process schemes has required investigation and development of new techniques in almost all phases of fluid catalytic cracking. The commercial unit that was recently put into operation at the Anacortes, Washington, refinery of Shell Oil Company climaxed several years of intensive research and development. The development of the process is summarized in this paper, along with a description of the Anacortes unit and its operation.

Experimental

Major portion of the experimental work described below was carried out by the Houston Manufacturing Research Laboratory of Shell Oil Company.

	First-Stage	Second-Stage
Temperature, F	875 to 1050	900 to 1000
Pressure, psi	16	16
Oil contact time, seconds	2 to 15	10 to 40
Catalyst/oil ratio	3 to 50	2 to 15
Stage conversion, per cent by volume	20 to 70	15 to 70
Overall two-stage conversion, per cent by volume	50 to 80	

*Paper presented before midyear meeting of the American Petroleum Institute's Division of Refining, in the Sheraton-Mount Royal Hotel, Montreal, Quebec, Canada, May 15, 1956.

Two pilot-scale catalytic cracking units were employed in the development of the cracking techniques and conditions used in the two-stage process. The first-stage unit, consisting of an upflow riser reactor, a stripper, a regenerator, and product fractionation columns, is capable of continuous operation at throughputs up to eight barrels of feed per day. Second-stage cracking of gas oil from the first stage was accomplished in two dense-bed pilot plants. One of these, which has been described in a previous publication,[12] operates semi-continuously at feed rates up to about one gallon per hour. The other dense-bed unit consisted of a modification of the dispersed-phase cracking pilot plant in which the stripper vessel was used as a dense-bed reactor. The ranges of cracking conditions investigated in most of the work were as follows:

Most of the pilot plant operation, employing two separate units, was equivalent to parallel flow of catalyst — that is, freshly regenerated catalyst was used in each stage. In other experiments, series flow was employed; i.e., partially spent catalyst from the first stage was used in the second stage.

Several commercial equilibrium catalysts and a wide variety of commercial and experimental feed stocks were used in these studies. However, except where otherwise stated, the results presented in this paper were obtained with West Texas flashed distillate and equilibrium microspheroidal catalyst withdrawn from Shell's Houston, Texas, refinery. During the pilot plant investigation, several large batches of this catalyst and feed were used. The properties shown in Table 1 and 2 are typical of the materials employed.

In addition to the development of cracking techniques and conditions used in the two-stage process, the engineering aspects of fluidization, catalyst transport, catalyst-gas separation, stripping, and regeneration were investigated on pilot plant, semicommercial, and commercial scales. These studies, which included the use of radioactive tracers and gamma-ray attenuation, involved detailed evaluations of the performance of six commercial units of varying designs. Stripper performance and the pressure drops and catalyst flow patterns in the standpipes and risers of these units were investigated extensively. A semicommercial stripper and a semicommercial riser capable of transporting one ton of catalyst per minute were operated to develop novel designs and to provide data on stripping and on catalyst flow. These same units and others were also used to obtain data for design of the high-capacity cyclones required for the separation of first-stage products from the catalyst.

TABLE 1. Catalyst properties.
(Commercial Equilibrium Synthetic Silica-Alumina)

Surface area, sq m per g	89
Pore volume, ml per g	0.25
Particle size distribution (by sedimentation), per cent by weight:	
<40 microns	6
40 to 50 microns	12
50 to 60 microns	19
60 to 70 microns	18
70 to 80 microns	15
80 to 90 microns	12
90 to 100 microns	9
<100 microns	9
Contaminants analysis, per cent by weight:	
Iron	0.12
Vanadium	0.003
Copper	0.0012
Nickel	0.003
Chromium	0.0041

TABLE 2. West Texas feed stock properties.

API	29.1
ASTM distillation, F:	
IBP	450
10 per cent by volume	540
50 per cent by volume	660
Pour point, F	+70
Ramsbottom carbon residue, per cent by weight	0.15
Sulphur, per cent by weight	0.57
Kinematic viscosity at 100 F, cs	13.5

Process Development

Short-Contact-Time Riser Cracking

The upflow riser-reactor pilot plant operated as the first-stage reactor demonstrated the advantages that can be obtained from short-contact-time riser cracking vs conventional fluid-bed cracking. The superiority of the riser technique is evident from Fig. 1 and 2, which show gasoline and carbon* yields, respectively, from riser and dense-bed cracking at both 900 and 1000 F.

Advantage of the riser is magnified at the higher temperature. In riser cracking, the increase in temperature serves to decrease coke production without affecting gasoline yield, whereas an accompanying decrease in gasoline is experienced in dense-bed processing.

Superiority of the rise technique shown in Fig. 1 and 2 is the result of three factors: (1) Establishment of uniform residence time and reduction of dilution of feed by cracked products due to the concurrent flow of catalyst and oil vapor, (2) better contacting

*In this paper, carbon yield is reported for pilot plant experiments; coke yield, including hydrogen associated with the carbon, is reported for commercial plant results.

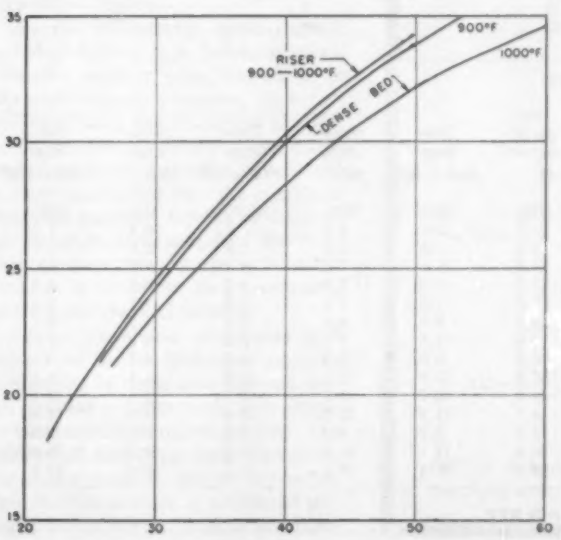

FIG. 1. Gasoline yields from riser, and from dense-bed conventional cracking.

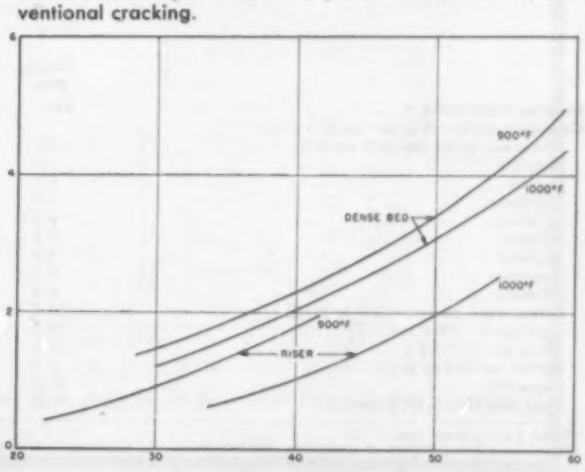

FIG. 2. Carbon yields from riser, and from dense-bed conventional cracking.

efficiency between catalyst and oil, and (3) higher average catalyst activity. These factors permit operation at high conversions with little destruction of cracked products, thereby resulting in lower coke and higher gasoline yields.

In addition to the above benefits of riser cracking, it was also found that the overall severity for achieving high conversions (70 per cent and higher) could be kept much lower in two-stage cracking. This is the result of processing the more refractory gas oil from first-stage cracking in the absence of the diluent gas and gasoline produced up to the first-stage conversion level.

After the feasibility and superiority of riser cracking had been established in principle, attention was turned to those questions that had to be answered before a successful integrated process design embodying the potential gains could be made.

Temperatures — Catalyst Flow

A detailed study of the effect of temperature variations in the two reaction stages was made. From the various possibilities, a higher riser (first-stage) temperature and lower second-stage temperature were chosen. This temperature sequence is obtained commercially with series flow of catalyst from the first to second reactor stage. Pilot-plant experiments in which series flow of catalyst was employed showed that the low level of coke deposited on the catalyst in the first stage has no effect on product distribution in the second stage.

The Author

A graduate of Hollywood High School in 1935, Dr. J. D. Heldman has gone "far afield" for a Californian, being now a special technologist in Shell Oil Company's New York office. He received BA and MA degrees in chemistry from the University of California at Los Angeles, then his PhD in physical chemistry at Stanford University in 1942. In the interval since then and now, he did graduate work at the University of California (Berkeley), worked on the Manhattan Project, joined Shell in 1945 and has been with the company since, at San Francisco, California, Houston, Texas, and New York.

First-Stage Conversion Level

The pilot-plant studies showed that the optimum first-stage conversion level was primarily dependent upon feed stock quality and dependent to a lesser extent on total conversion and temperature sequence. The overall catalytically cracked gasoline yield obtainable peaks rather sharply at a particular first-stage conversion for any given feed and coke made. The first-stage conversion that leads to a maximum gasoline may not be optimum from an economic standpoint, of course, depending on the downstream processing facilities: For example, polymerization vs alkylation of olefins, the marketing situation, and other factors. Economic evaluations using typical product values showed that first-stage operation at conversions differing somewhat from optimum does not incur significant economic penalties. This is an important consideration in process flexibility.

Applicability to Various Feed Stocks

In order to determine the general applicability of the two-stage process to widely different feed stocks, several commercial and experimental stocks were investigated. Comparisons for some of these feeds are summarized in Table 3. With the West Texas feed, two-stage cracking permits the highest conversion at constant carbon yield; conventional recycle operation gives yields intermediate between those from single-stage and two-stage cracking. Similar results are obtained with other feeds of widely differing quality, as indicated by the single vs two-stage comparisons for Redwater and Los Angeles Basin flash distillates shown in Table 3.

Differences in the yields of gaseous hydrocarbons are due in part to the cracking temperatures employed in the comparisons and in part to the processing techniques. At constant temperature and conversion, less dry gas is produced in riser cracking than in dense-bed operation, but the trend of increasing gas production as temperature is raised holds with either method of operation. These two factors explain the increased gas make for the two-stage cracking results shown for West Texas and Redwater compared to

TABLE 3. Comparison of single-stage and two-stage cracking of various feed stocks.

	West Texas			Redwater		Los Angeles Basin	
Crude source							
Feed properties:							
API gravity	29.1			23.0		25.2	
Sulfur, per cent by weight	0.57			0.70		1.25	
Ramsbottom carbon residue, per cent by weight	0.15			1.0		0.3	
Precision distillation, per cent by volume:							
IBP to 450 F	3			1		1	
450 F to 615 F	35			9		27	
615 F+	62			90		72	
	Single-stage						
	Single pass	Total gas oil recycle*	Two-stage	Single-stage	Two-stage	Single-stage	Two-stage
Cracking temperatures, F	900	900	1000 to 900	900	1000 to 900	1000	1000 to 950
Catalytic cracking yields, per cent by volume:							
Ethane and lighter (std cu ft per bbl)	(190)	(190)	(300)	(195)	(230)	(415)	(290)
Propylene	7.6	7.1	9.5	4.9	7.5	6.4	7.8
Propane	4.2	3.8	3.8	3.2	2.9	3.9	3.7
Butylenes	8.2	8.8	10.9	7.0	8.8	8.1	9.0
Isobutane	9.4	8.3	4.5	5.8	3.9	3.8	4.6
n-Butane	1.8	1.5	1.5	1.1	0.8	1.1	0.9
Amylenes	4.8	5.5	6.6	4.9	7.6	5.2	6.4
Isopentane	6.5	6.9	3.8	4.5	2.6	2.0	2.5
n-Pentane	0.3	0.3	0.3	0.4	0.3	0.4	0.1
Depentanized gasoline (113 F to 450 F)	24.2	32.2	37.5	33.5	41.9	28.8	38.6
Light gas oil (450 F to 615 F)	23.5	19.3	16.7	17.9	13.2	22.6	19.4
Heavy gas oil (615 F+)	18.0	14.7	11.2	20.5	12.8	18.9	11.8
Carbon, per cent by weight	5.2	5.2	5.2	8.5	8.5	6.5	6.5
Conversion	58.5	66.0	72.1	61.6	74.0	58.5	68.8
Total yield of 10 lb RVP gasoline†	49.9	59.5	67.4	55.5	67.7	50.8	64.8

*Total feed + fresh feed = 1.6.
†Based on polymerisation of propylene and butylenes, and blending butane to 10 lb RVP.

single-stage cracking at 900 F, and the decreased gas make for Los Angeles Basin compared to single-stage operation at 1000 F.

Product Quality

Major differences in quality of the products from conventional single-stage and the present two-stage cracking process are in the compositions of the gasolines as shown in Table 4. Properties of the final gas oils produced by the two techniques are essentially the same when compared at constant conversion. The differences that do exist can be explained largely on the basis of the different conversions obtained at a given coke yield.

Despite the large variations in the compositions of the gasolines produced in the various processes, the leaded Research method octane ratings of these gasolines are essentially the same. The calculated Research method + 3 cc TEL ratings of the total 10 lb RVP gasolines from all the processes fall in the range 100.0 to 100.5 octane number.

The higher olefin and lower aromatic content of two-stage gasoline result from the fact that a very substantial portion of the gasoline is produced in the first stage where the conditions are such that olefin saturation and recracking are avoided. While the total amount of aromatics in the various gasolines does not vary widely, the concentration of aromatics in two-stage gasoline is much lower due to the increased amount of olefins produced.

The somewhat higher sulfur content of two-stage gasoline is also attributed to avoidance of recracking. This increase in sulfur does not present a serious problem with most U. S. crudes; however, special treating techniques will probably be required with some high-sulfur crudes.

Because of the high olefin content and the relatively high diolefin content, extensive stability tests, including an 18-month storage program, were carried out. Since the first-stage gasoline would be expected to be the least stable portion of the total gasoline, it was used in these tests rather than the combined two-stage gasoline. Results of the storage program indicated that the first-stage gasoline, when properly inhibited initially, is as stable as conventional catalytically cracked gasoline.

Engine cleanliness tests were also carried out on the first-stage gasoline. The results of these tests showed that this gasoline is comparable with a typical commercial premium gasoline. The stability of first-stage (and, therefore, two-stage) gasoline, despite the rather high diolefin content, is attributed primarily to the boiling range of the diolefins. Analysis of several fractions of the gasoline showed that the diolefins are concentrated in the lower boiling portion, which do not contribute markedly to gum formation.

TABLE 4. Properties of products from two-stage and conventional catalytic cracking.

	Single-Stage		
	Single Pass	Recycle	Two Stage
Carbon yield, per cent by weight	5.2	5.2	5.2
Conversion, per cent by volume	59	66	72
Product properties:			
Depentanized gasoline			
API gravity	45.5	46.3	46.0
Sulfur, per cent by weight	0.80	0.08	0.14
Maleic anhydride value	8	7	18
Hydrocarbon type analysis, per cent by weight:			
Olefins	16	26	43
Aromatics	50	44	37
Saturates	34	30	20
Octane ratings (neat):			
Research method +3 cc TEL	98	98	98.5
Light gas oil			
API gravity	28.0	27.3	26
Aniline point F	123	116	113
Kinematic viscosity at 100 F, cs	3.2	3.1	3.0
CFR calculated cetane number[23]	37	35	32
Heavy gas oil			
API gravity	23.5	22	20
Ramsbottom carbon residue, per cent by weight	0.8	0.3	0.7
Kinematic viscosity at 100 F, cs	14	13	13

Flexibility

One of the most important considerations in the development of a process is the degree of operating flexibility that can be obtained. In the Shell two-stage cracking process, considerable flexibility is available for changing the yield structure from any given feed stock. For example, gasoline yield can be increased further by incorporating recycle into one of the cracking stages. On the other hand, in periods of high demand for intermediates, the yield of light gas oil can be increased substantially by charging only heavy gas oil to the second stage.

A comparison of two types of two-stage operation, namely, with total first-stage gas oil and with heavy first-stage gas oil only going to the second stage, is shown in Table 5. These data are on the same basis (5.2-per-cent-by-weight carbon) as, and therefore comparable with, the West Texas data given in Table 3. The 9 per cent increase in light gas-oil yield is realized partly at the expense of heavy gas oil and partly because of the lower total conversion. However, despite the increased light gas-oil yield and the 5 per cent lower conversion, the gasoline yield is decreased only 4 per cent. Furthermore, the light gas oil produced in this way is of high quality. Of course, gains in yield and quality could be achieved in conventional recycle operation by recycling only heavy gas oil, but the difference between comparable two-stage cracking and recycle cracking operations would be essentially the same as that shown in Table 3. It is significant, however, that the two-stage process operated for maximum intermediates rather than maximum gasoline, i.e.,

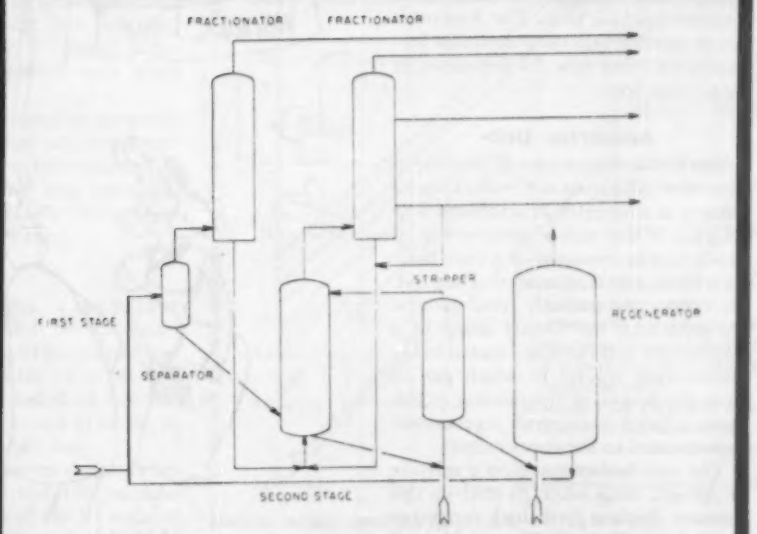

FIG. 3. Schematic flow diagram of Anacortes (Washington) catalytic cracking unit.

cracking of only heavy gas oil in the second stage, produces 3 per cent more gasoline than conventional recycle cracking of total gas oil at roughly the same total conversion.

TABLE 5. Two-stage yields from cracking total first-stage gas oil vs. heavy first-stage gas oil in the second stage.

	Second-Stage Feed	
	Total Gas Oil*	Heavy Gas Oil†
Total conversion, per cent by volume.	72	67
Yields, per cent by volume:		
Debutanized gasoline (IBP to 450 F)	48.2	43.8
Light gas oil (450 F to 615 F)	16.7	25.8
Heavy gas oil (615 F+)	11.2	7.6
Carbon, per cent by weight	5.2	5.2
Total 10 lb RVP gasoline, per cent by volume‡	67.4	62.7

*Total feed to both stages ÷ fresh feed = 1.6
†Total feed to both stages ÷ fresh feed = 1.3.
‡Based on polymerization of propylene and butylenes, and blending butane to 10 lb RVP.

Engineering Features

Extensive experimentation on equipment of sizes ranging from small laboratory units to commercial plants demonstrated the practicality of all new features of two-stage designs. In particular, the characteristics of catalyst-oil-vapor riser flow and of high-load separation devices were established over very wide ranges of operating conditions. These studies have shown that practical designs can be made to cover a wide scope of operating requirements.

Additionally, as a result of Shell research, there have been significant advances in stripping and regeneration techniques in the past few years. Some of these improvements were previously incorporated and tested in other Shell catalytic cracking units. The Anacortes design incorporates these desirable features, plus other new developments, in the process flow.

Anacortes Unit

The first commercial unit employing these new techniques was built at Shell's refinery at Anacortes. A schematic flow diagram of this unit is given in Fig. 3. Fresh feed is contacted in a riser reactor with regenerated catalyst. The product vapors and partially spent catalyst are separated, the former going to a fractionator and the latter routed to the second-stage reactor to which gas oil from the first-stage fractionator is fed. Spent catalyst is stripped, regenerated, and returned to the riser reactor.

The unit has operated on a mixture of Alberta feeds since its start-up this January. Typical feed stock properties are shown in Table 6. Plant yields with this feed mixture are given in Table 7.

The plant exceeded design expectations and has demonstrated ability to operate smoothly without mechanical problems of any consequence.

TABLE 6. Alberta feed stock properties.

API gravity	23.7
ASTM distillation ,F:	
IBP	508
10 per cent by volume	620
Pour point, F	+85
Ramsbottom carbon residue, per cent by weight	0.83
Sulfur, per cent by weight	1.26
Viscosity at 210 F, SUS	51

TABLE 7. Catalytic cracking of mixed Alberta feed stock at Anacortes.

	Yields (Per Cent by Volume)
Ethane and lighter (std cu ft per bbl)	(340)
Propylene	8.0
Propane	4.5
Butylenes	12.7
Butanes	5.1
Debutanized gasoline	53.3
Light gas oil	12.2
Heavy gas oil	12.4
Coke, per cent by weight	6.5
Conversion	75.4

Other Designs

The principles involved in the Anacortes unit are not limited to this design. For example, single-stage riser reactor units have been designed to take advantage of the increased selectivity where high conversion is not required, as in the case in some refining situations. Existing fluid units can, in some instances, be modified to take advantage of the short-contact-time and two-stage principles by addition of a riser reactor and other facilities.

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VISITORS DAY
WELCOME TO THE RIVARUN REFINERY OF THE SLIPRY PETROLEUM CO
"YES MA'AM, WE CALL IT A REFINERY BECAUSE IT MAKES ALL OF US SO REFINED..."

Three VTI Scales (A, B & C) were originally presented at the Fourth World Petroleum Congress, June 10, 1955, Rome, Italy, in response to a resolution by the Third World Petroleum Congress at the Hague in 1951. This resolution called for an index for viscosity/temperature relation founded on a sounder theoretical basis than that of the Dean and Davis viscosity index VI.

As a result of the authors' presentation, the Fourth World Petroleum Congress passed a resolution, "that consideration of the authors' proposal should be referred to a responsible technical and scientific standardization body." Consequently, the revised VTI scales (A and C) were presented to ASTM Research Division VII, Symposium on Methods of Expressing Viscosity Index, February 7, 1956, Dallas, Texas. After studying the various proposals, the authors and others have adopted the VTI "A" scale as it has many advantages and gives the best solution of the viscosity/temperature problem. For this reason, the VTI "A" scale is presented here under the name of VTI, with full details and tables for its evaluation.

New Viscosity Index En Route to Adoption

A more exact and scientific viscosity index (VI) system has been developed and is under study by ASTM and other technical bodies

C. M. Larson and W. C. Schwaderer
Sinclair Refining Company

EXCLUSIVE

MANY methods have been suggested to express the viscosity/temperature relation, possibly by one single number or a function, which have been conveniently classified into "non-relative" (absolute) and "relative" indices.

In non-relative indices, the derived number is free from any connection with the properties of known materials or standard series of oils—these indices are a direct measure of temperature susceptibility. Relative indices relate the viscosity/temperature characteristics of a given oil to some reference or family series and are, therefore, a classification based on temperature susceptibility. In practice only a relative index can be satisfactory since a mental comparison with some known reference value is always made.

While we would all welcome a more fundamental approach to the viscosity/temperature relationship than any now existing, there is reason to believe that even after this relationship is fully established and accepted, it is likely that some empirical relative index will still be used to satisfy the need so far met by the present Viscosity Index (VI).

Viscosity Index (VI)

Fig. 1 shows the L and H reference series of the present VI with the viscosities at 100 F plotted against the viscosities at 210 F, both in terms of the Walther-ASTM coordinates of log.log. (v + 0.6). Also shown are lines for VI = 50, 150 and the permanent viscous series "P" (described below). First we observe the erratic curves of the L and H series of oils and their minor variations from a straight line.

Then the fact should be noted that the uneven divisions between VI = 0 and 50, 50 and 100, 100 and 150 increase steadily, producing an excessive sensitivity of the VI scale at its lower end, over-rating small improvements, and lack of sensitivity at its upper end, with the result that improvements over VI = 100 are not duly expressed by the VI scale.

Finally, when the VI is extrapolated above 100, double

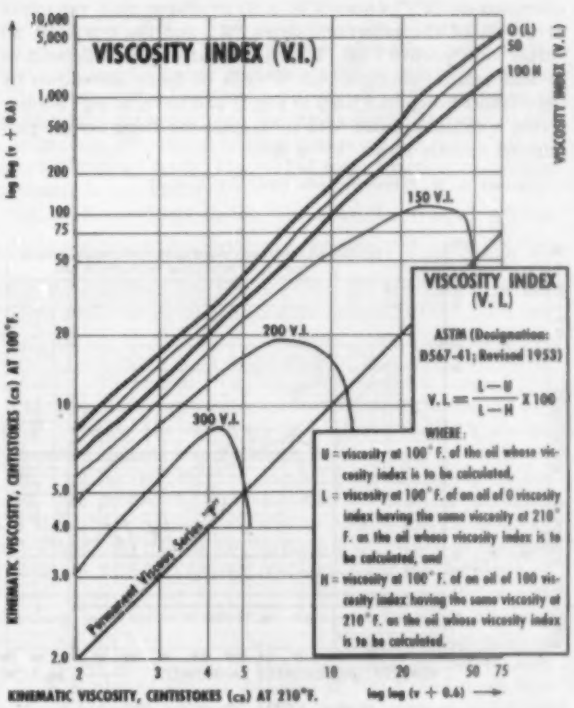


FIG. 1. Curves showing the L and H reference series of the presently employed viscosity index system (Dean & Davis).

meaning values are obtained since one set of viscosity data can produce two VI values, an oddity due to the recurring curvature of the VI lines.

Other deficiencies of the VI will not be covered here, but attention should be drawn to the unwarranted accuracy in reporting the VI indices. Goettner[1] states: "The tables for the determination of the Viscosity Index contain 5 figure numbers (even 6 figures until 1952), and give the uncritical user the illusion of an accuracy which is not reached at all in viscosity measurements. *A value should never be expressed in more figures than are beyond measurement.* Then we should be able to determine the viscosity at least to 0.01 per cent exact. In reality, the measurement error is considerably greater and, in practice, lies near ± 1 per cent. Even with the greatest care and using an adequate set of instruments, we hardly can lower the error below ± 2 per cent." Many years ago, another scientist stated that "this super-precision of VI seems to be rather like taking surgical instruments to chop firewood." Therefore, the authors' suggestion in the following to report the VTI by three figures (maximum four) seems to be sound and fully adequate.

Viscosity-Temperature Index (VTI)

The Viscosity-Temperature Index (VTI, formerly VTI_A) is expressed by the equation:

$$VTI = \frac{\log\log(U + 0.6) - \log\log(v_{210} - 0.6)}{\log\log(R + 0.6) - \log\log(v_{210} + 0.6)} \times 100$$

$$= \frac{W_U - W_{210}}{W_R - W_{210}} \times 100. \quad . \quad . \quad . \quad . \quad (1)$$

The values involved in this equation are based on the accepted ASTM Standard Viscosity-Temperature Chart for Liquid Petroleum Products (D341). The viscosity/temperature curves of Newtonian fluids can be portrayed as straight lines on this chart. Fig. 2 (representing a section of the ASTM Chart) shows the viscosity/temperature curve of an unknown oil "U," whose VTI is to be determined, the curve of an oil of the reference series "R" and the curve of an "ideal" or "perfect" oil "P" whose viscosity is independent of temperature changes. All "P" oils or fluids are shown by the parallel horizontal lines in Fig. 2 and have, at all viscosity levels, a constant index VTI = 0, since the slope for the permanent viscous series "P" is zero.

[1]Goettner, G. H., Schmiertechnik, 1954, Heft 2, 41-47.

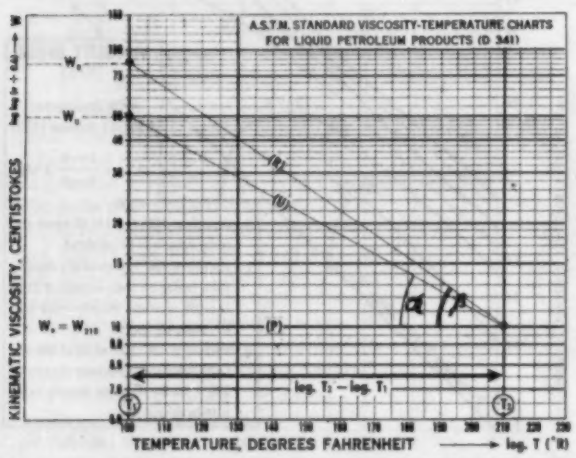


FIG. 2. A section of the ASTM VI chart (D341) showing viscosity/temperature curves of an unknown oil "U"; an oil of the reference series "R"; and of a perfect oil "P," whose viscosity is independent of temperature changes.

The viscosity/temperature relationship of these oils U, R and P is valid for any pair of selected temperatures and it is, therefore, not necessary to refer them to only 100 F and 210 F. However, for an index intended for general practical use, the temperature range has to be pre-established and, therefore, the 100 F and 210 F are the preferred temperatures for the calculation of the VTI.

These two temperatures located on the abscissa of the ASTM Chart (see Fig. 2) are expressed by:

T is the Absolute Temperature, i.e.

T = Rankine (459.69 + Temperature F)

while the ordinate values

W = log log (v + 0.6), which is the double logarithm of the kinematic viscosities plus a constant 0.6.

If these viscosities are below 1.5 cs, 1.0 cs or 0.7 cs, then the corresponding constants should be 0.65, 0.70 and 0.75 respectively.

Returning again to Fig. 2, the Walther/ASTM steepness or slope factor m for a given oil U is, therefore:

$$\text{Tan. } \alpha = m_U = \frac{W_U - W_P}{\log T_2 - \log T_1} \quad . \quad . \quad . \quad (2)$$

Since W_P is independent of the temperature interval, this value can be replaced by W_{210}, which is a common value for the three oils U, R and P because of their equal viscosity at 210 F as defined (see Fig. 2). Equation (2) can, therefore, be written:

$$\text{Tan. } \alpha = m_U = \frac{W_U - W_{210}}{\log T_2 - \log T_1} \quad . \quad . \quad . \quad (3)$$

This ASTM slope, by itself, cannot be taken to classify the viscosity/temperature relationship of oils, because m decreases with increasing viscosity level and allots different values to oils of the same series. Therefore, m must be related to some reference oil.

The slope m for the reference oil R is determined by the following equation:

$$\text{Tan. } \beta = m_R = \frac{W_R - W_{210}}{\log T_2 - \log T_1} \quad . \quad . \quad . \quad (4)$$

There are two possible methods of interrelating these two expressions (Equations 3 and 4) to obtain a relative index of VTI behavior:

a) Conventional Scale:

$$\frac{m_R - m_U}{m_R} = \frac{(W_R - W_{210}) \,/\, (\log T_2 - \log T_1) - (W_U - W_{210})/(\log T_2 - \log T_1)}{(W_R - W_{210})/(\log T_2 - \log T_1)}$$

$$\frac{W_R - W_U}{W_R - W_{210}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

In this case, the value 0 is obtained for U = R and the value 1 for U = P(v_{210}). This formulation corresponds to the present ASTM — VI equation:

$VI = \frac{L - U}{L - H}$, where L is substituted by W_R and H by W_{210} = W_P (see Fig. 1).

b) Inverted Scale:

$$1 = \frac{m_R - m_U}{m_R} = \frac{m_U}{m_R} = \frac{(W_U - W_{210}) \,/(\log T_2 - \log T_1)}{(W_R - W_{210})/(\log T_2 - \log T_1)}$$

$$= \frac{m_U}{m_R} = \frac{W_U - W_{210}}{W_R - W_{210}} \quad . \quad . \quad . \quad . \quad . \quad (6)$$

In this case, the value 1 is obtained for U = R, and the value 0 when U = P(v_{210}).

[2]Goettner, G. H., Proceedings Fourth World Petroleum Congress, Section V/A, Paper 12, received subsequent to section meeting.
Goettner, G. H., ASTM Research Division VII, Symposium on Methods of Expressing Viscosity Index, February 7, 1956, at Dallas, Texas.

Equation 6 is without doubt more straightforward than Equation 5. It is helpful here to quote Goettner,[2] who arrived at the same formulation (Equation 6) in a somewhat different way (with certain nomenclature changes by the authors):

> "If Equation 6 is multiplied by 100, the expression acquires a particularly clear meaning. It tells the per cent relationship the tested material has of the (temperature coefficient) value of the reference (normal) series "R." It is the mean relative temperature coefficient of viscosity in per cent over temperature $T_2 - T_1$. True, this index results in a different ranking from the Viscosity Index (VI), since oils of permanent viscosity (P) in accord with Larson and Schwaderer's suggestions, are assigned the index zero, while oils of the reference Series "R" are assigned the value 100."

Multiplying Equation 6 by 100, the VTI is then expressed by Equation 1 as previously stated:

$$VTI = \frac{W_U - W_{210}}{W_R - W_{210}} \times 100 \quad . \quad . \quad . \quad . \quad (1)$$

Detailed "Practical Calculation of Viscosity-Temperature Index (VTI)," with table, is given in the last section.

Reference Line "R" (Formerly R_A)

Fig. 3 shows the straight reference line "R" based on two arbitrary oils of the Dean and Davis — ASTM "H" series, which were selected so that VI = 100, Hersh, Fisher and Fenske KVI = 100 and the straight line R = 100 agree perfectly. In fact, the R series is almost identical with the KVI = 100 series for 210 F viscosities above 4 centistokes. This KVI = 100 series forms a curve that deviates less than 1 per cent from a straight line at the maximum curvature. Thus, the selection of the straight Reference Line "R" by the authors is justified. Since the VTI covers all liquids, this Reference Line "R" may be considered as the perfect representative of petroleum oils.

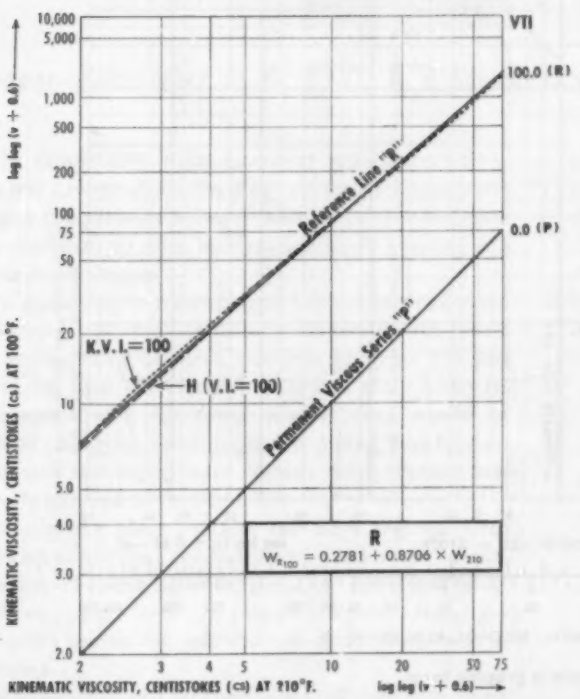


FIG. 3. Three reference lines for VI systems — See under "Reference Line" "R" (Formerly R_A).

Calculations of Values for (R)

Reference Line "R" is defined by the following two points:

210 F	100 F
4.0 cs	20.59 cs
75.0 cs	1925.00 cs

The slope m of R, is, therefore, calculated by the equation:

$$m = \frac{W_{1925} - W_{20.59}}{W_{75} - W_4} = 0.8706 \quad . \quad . \quad . \quad (7)$$

The relation between the viscosity at 100 F and the viscosity at 210 F for all points of the line R is expressed by this equation:

$$W_{R100} = W_{1925} - m\,(W_{75} - W_{210}) \quad . \quad . \quad (8)$$

therefore

$$W_{R100} = 0.5164 - 0.8706\,(0.2738 - W_{210})$$
$$= 0.2781 + 0.8706\,W_{210} \quad . \quad . \quad . \quad . \quad (9)$$

The 100 F viscosity of R can, therefore, be calculated for any selected 210 F viscosity by Equation 9. However, Table 1 gives the calculated 100 F Kinematic Viscosity values of R for the corresponding 210 F viscosity from 2 to 75 centistokes.

Fig. 4 shows the VTI scale in graphical form. The distance between "R" (VTI + 100) and "P" (VTI = 0) is equally divided by straight lines, giving perfect sensitivity over the whole scale. Therefore, irregularities of the present VI due to the "waviness" of its reference series are eliminated. Likewise, anomalous values, such as occur in the case of oils having a high VI index figure (low VTI) are avoided (See Fig. 1 for comparison).

The straight reference line "R," characterizing oils of different viscosities of similar production from one typical crude by the constant VTI + 100, guarantees the proper classification of lubricating oils ("families" of oils) since most lubricants produced today are in close proximity of the "R" series.

Here it may also be pointed out that the VTI may be used for blending purposes since the Walther-ASTM function W is, in general, considered additive and is used in the construction of Blending Charts. The ASTM slope function "m" when unrelated, is not additive.

Fig. 5. Rumpf[3] has shown that when the Walther-ASTM slope constant m-values of the VIT formula $\frac{m_U}{m_R}$ (Equation 6) are plotted against 210 F viscosities, the resulting lines are straight and form equal divisions with respect to m-values and viscosity. ASTM-VI = 0, 50, 100 and 150 are drawn for comparison, and again it is quite evident that the VTI is far superior to the present VI system over the entire range.

Fig. 6 shows the extension of the VTI down to the 0.4 cs/210 F viscosity. The values for "R" below 2 cs/210 F viscosity can be calculated by Equation 9.

Fig. 7. The definition of the VTI system, based on the "ideal" or permanent viscous series P and the accepted ASTM-Walther coordinates, readily permits the extension of the method into regions not heretofore accessible to the generalizations based on former concepts. Since the definition of P is so simple, it can be extended into any viscosity region. Likewise, the reference line "R" can be extended to lower or higher regions by using the accepted ASTM chart principles. Fig. 7 shows an example of this application, where viscosity at 32 F is plotted against viscosity at 100 F and fluids like gasoline, kerosine, solvents, alcohols and water are plotted.

[2]Rumpf, Kurt K., Proceedings Fourth World Petroleum Congress, Section V/A Paper 12, 206.
Rumpf, Kurt K., ASTM Research Division VII, Symposium on Methods of Expressing Viscosity Index, February 7, 1956, at Dallas, Texas.

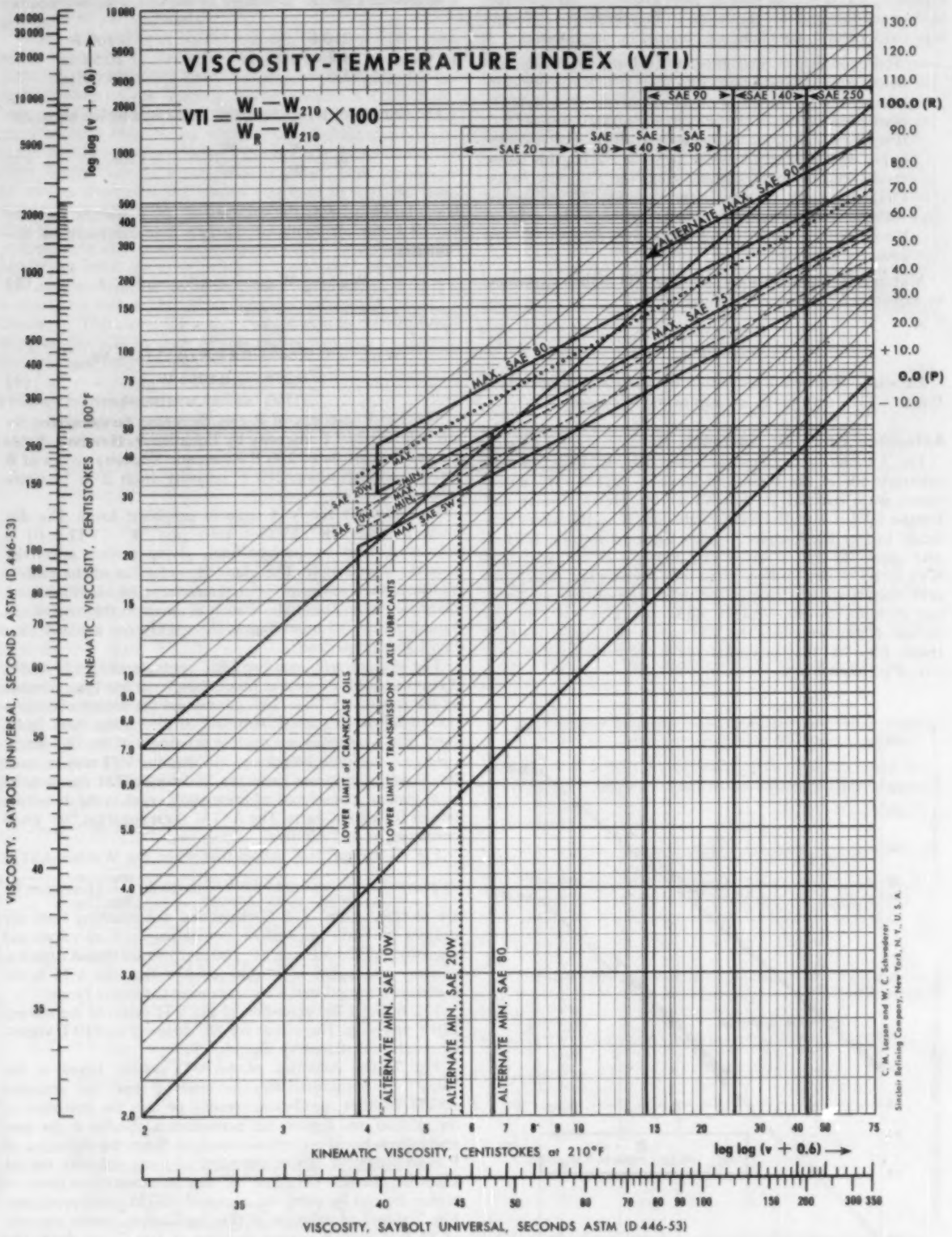
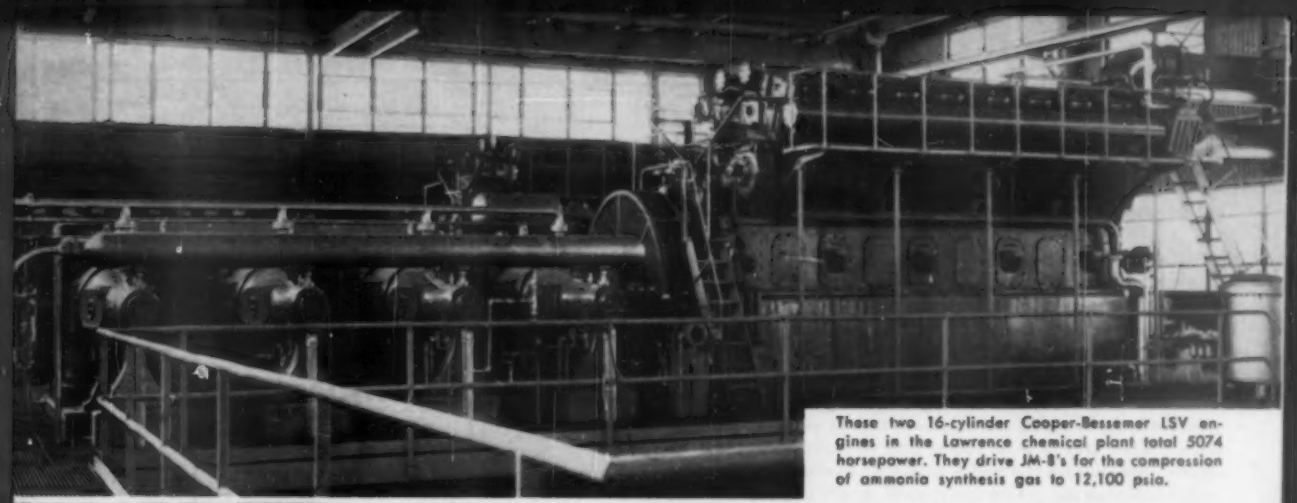


FIG. 4. The VTI scale in graphic form.

Second part of this article will appear in an early issue.



These two 16-cylinder Cooper-Bessemer LSV engines in the Lawrence chemical plant total 5074 horsepower. They drive JM-8's for the compression of ammonia synthesis gas to 12,100 psia.

This view of the C.F.C.A. plant at Lawrence, shows the two 8-cylinder LS engines driving JM-5's for the efficient compression of air, natural gas and nitrogen.

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Refining Methods for Waxes, Asphalts, Greases and Compounded Oils.

Chapter III

Modern Methods Have Changed "Waste" Materials into Important Commercial Products.

Dr. V. A. Kalichevsky

Consulting Chemical Engineer

WAXES, asphalts, greases, and compounded oils are petroleum products. They find special applications in the industry and at home. Many of them may include a substantial quantity of ingredients of non-petroleum origin. Companies handling such products are often independent concerns buying the basic materials in bulk quantities for blending purposes. The asphalt industry may be regarded as the one standing in its own right.

Waxes

Wax finds a wide use both in industry and in the home. This may not be generally realized because its presence in products reaching the market is often concealed by other ingredients. The uses for wax were developed gradually in the course of the last two or three decades until its annual sales approached half a million tons or 3,500,000 bbl.

In the past, wax was regarded as waste material. It was sent to cracking stills in order to increase the recovery of gasoline from crude oil. Large quantities of wax are still disposed of in a similar manner, waiting for the discovery of additional markets that would make further increase in its production profitable.

Petroleum contains two different types of waxes, paraffin wax and microcrystalline wax.

Paraffin wax is a well-known substance finding wide use in the manufacture of candles and sealing wax. It has a distinct luster, a white, somewhat milky appearance, and is semi-transparent. The milky appearance is caused by the presence of air-bubbles that are formed when the wax solidifies and releases the gases it dissolves in the molten state.

The paper industry accounts for 80 per cent of its total consumption. Paper milk bottles, drinking straws, bread wrappers and paper sizings represent some of its uses. During the war, when metal shortage was acute, the ability of wax to waterproof paper was utilized to its fullest extent, releasing large quantities of strategic materials to the army. In many instances, these substitutes were found to be more satisfactory than the previously used materials and were retained for peacetime use. Candles are made from paraffin wax, which has largely replaced beeswax and other candle waxes. Paraffin wax has a decided advantage over such waxes, not only in price but also because of improved performance and ability to withstand relatively high temperatures without softening. The use of paraffin wax for preserving food and materials that are perishable on contact with air or moisture is familiar to housewives. Furniture polishes contain paraffin wax as one of their most important ingredients. Wax fuel tablets for camp cooking and for thawing out frozen pipes are available. Some of the less-known uses include the manufacture of windows for chicken houses, because wax transmits more ultraviolet rays than glass, resulting in healthier hens and higher egg production.

The other type of wax is known as microcrystalline wax. This wax is made by removing oil from petrolatum obtained in dewaxing residual stocks. Microcrystalline wax is of a slightly yellowish to black color depending on the degree of refining. While paraffin wax has a distinct crystalline structure, the structure of microcrystalline wax is well concealed, and for many years, it was believed that its chemical nature might be closer to asphalt than to wax. The name microcrystalline signifies that powerful optical methods are required to discover the presence of crystals. Formerly, it was referred to as amorphous wax. The melting point of microcrystalline wax is higher than that of paraffin. The differences in these and other physical properties are such that the two types of waxes must be treated differently.

Microcrystalline waxes first appeared on the market in 1926 in commercial quantities. By 1939, their production was 20,000,000 lb, and in 1944, due to the tremendous quantities consumed in packaging military supplies, 120,000,000 lb were produced. They are used for coating and impregnating electrical equipment, for paper coatings, in cosmetics, in the manufacture of carbon paper and for waterproofing.

Paraffin Wax

Paraffin wax is associated with lubricating oil distillates and petrolatum with residue. Rod wax, which separates from the crude oils in the wells around the sucker rods, has a very high melting point and on this basis should be classified as petrolatum, but in its appearance it is close to paraffin wax. This is another evidence that no sharp breaks occur in the properties of hydrocarbons found in crude oil. Paraffin wax and petrolatum, the two waxes familiar to the refiner, are handled differently because of their dissimilar structure.

Paraffin wax from the dewaxing operation is obtained in

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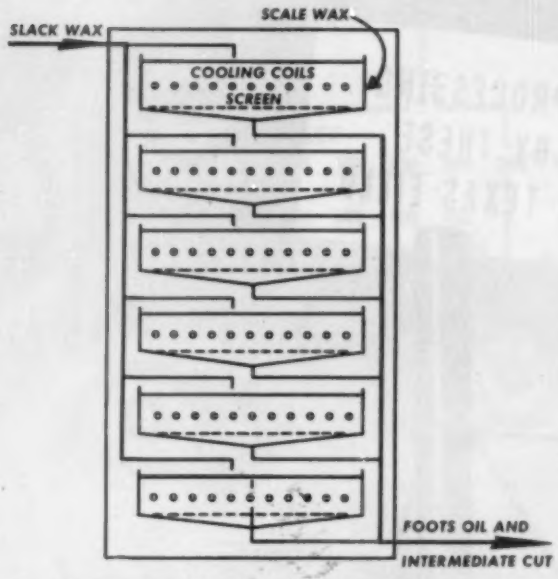

FIG. 1. Old-Fashioned wax sweating unit, wherein "scale" or crude wax is separated on the basis of melting-point ranges.

the form of "slack wax." To separate oil from the slack wax, sweating or solvent-pressing may be employed. Sweating is conducted in large pans located in specially designed rooms or "sweaters," which are shown diagrammatically in Fig. 1. Sweating pans contain screens fastened to the sides of the pans a few inches from the bottom and serve to support the wax cake. Rows of pipes carrying cold or hot water for controlling the temperature of the wax cake are located at close intervals above the screens. Provision is made for regulating the temperature of the air inside the sweaters. In modern installations, their operation is practically automatic during the sweating period.

Sweating pans are charged with water up to the screen level, and molten wax is pumped on top to form a layer about six inches thick. Wax is solidified by circulating cold water through the pipes. Water is drawn from the bottom of the pans, leaving the wax cakes suspended on the screens. The temperature of the wax cake is gradually raised at the rate of one to two degrees Fahrenheit per hour by circulating warm water through the pipes and adjusting the air temperature.

When the wax begins to melt, oil and the low-melting point waxes are liquefied, leaving on the screen the higher melting-point waxes. The liquefied fractions are continually drained from the sweating pans into special receptacles. The first portions form "foots oil" and are discarded. The subsequent portions, known as "intermediate cut," contain both oil and wax, and are collected. Sweating is continued until the wax cake, or "scale wax" remaining on the screen, reaches the desired melting point. The "scale wax" is then melted and removed from the sweaters. Scale wax may be marketed directly, but higher grades require finishing by percolation through clay or bauxite. Occasionally, an acid treat or caustic wash may precede filtering or sweating operations.

Separation between the various melting-point waxes is not sharp, and the intermediate cut contains some of the high-melting waxes that are recovered by blending it with the fresh feed. The intermediate cut can also be sweated separately for the production of low-melting point waxes. A complicated system of recycling is used that consists of blending and reblending the cuts obtained from such operations. In working out these recycling schemes, the existence of waxes having different melting points should not be overlooked. The same applies to all operations of this type, including dewaxing of oils, when two distinct products are made. Hydrocarbons of intermediate nature must have an escape somewhere or they will accumulate in the system.

Melting point of a wax is not an indication whether it is a wax of this particular melting point or a mixture of low and high-melting waxes. Some operators think that an elaborate recycle scheme can resolve any intermediate cut into oil and high melting-point wax, which is an impossibility. Waxes that do not meet specifications must be discarded as otherwise they will overflow the system.

The sweating process is far from being ideal. Recovery of wax is incomplete, and much of it is lost with the oil unless a satisfactory recycling scheme is established. Sweating, however, is cheap. Wax is not an expensive commodity, and sweating is frequently more economical than the modern processes insuring higher wax yields.

The modern processes for deoiling paraffin wax include solvent-pressing. Slack wax is thoroughly mixed with naphtha or solvents used in dewaxing oils. The mixture is chilled and passed through a filter press. The chilling temperature and the quantity of solvents employed determine the melting point, oil content, and other properties of the recovered wax.

Deoiling of petrolatum cannot be accomplished by sweating or by filtering with naphtha. The wax present in residual stocks forms small crystals that settle out as a slimy precipitate. Petrolatum, however, can be freed from oil by centrifuging it with naptha or by diluting it with special solvents and filtering. These solvents include benzol-acetone mixtures employed in the benzol-ketone process. Melting point, oil content, and other properties of wax are controlled by adjusting the filtering or centrifuging temperature, the quantity and nature of solvents, or the boiling range of the naphtha employed. The separated microcrystalline wax is usually finished by percolation through clay.

Wax is often sold in the form of cakes or slabs weighing from ¼ to 12 lb. These cakes are prepared by molding. A modified plate and frame press is used for this purpose. The assembly consists of the molds and cooling plates through which water circulates. Molten wax is poured into the molds and allowed to solidify. The press is then opened and the cakes removed manually. This is a batch process requiring much labor and having all the inconveniences for this type of operation.

A new continuous wax molding process shown in Fig. 2 is now coming into general use. The molten wax is poured into the molding pans placed on a moving belt. The quantity of wax poured into the pans is controlled by discharging through pistons that act as measuring devices. The pans pass through a cooling compartment where the solid wax cakes are formed. Cooling is done by a stream of cold air. The cakes are removed from the pans automatically and the pans resume their traveling cycle. Packaging of the wax cakes is also automatic. The process is applicable to all types of waxes.

Another continuous process for preparing wax slabs is applicable to the microcrystalline wax. Wax is extruded in the form of a strip of uniform thickness. The strip is cut into the cakes of required size.

Petroleum jelly and the product sold under the trade name "vaseline" are made from crude petrolatum. Petroleum jellies are manufactured for pharmaceutical and technical uses. Two types are known—natural and artificial. The former is obtained as a residue from the distallation of paraffin-base crude oils; the latter is prepared by blending selected fractions of oil. Pharmaceutical jellies

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Recently installed in the Texas field of a major petroleum producer, these two Wickes boilers assure delivery of the steam at proper uniform temperature and pressure to separate liquids and undesirable components. Wickes boilers are often chosen by petroleum companies, not only for field processing operations, but also for a dependable source of steam in refineries. The units shown here are Wickes Type A-2 shop-assembled water tube boilers, each with a design pressure of 275 psi and an operating pressure of 260 psi.

Other Wickes Type-A shop-assembled boilers are engineered for pressures up to 1,000 psi and steam temperatures up to 750°F., with sustained steam production up to 60,000 lbs. per hour. They are protected by pressure-tight steel casings which are completely weatherproof for outdoor installation. Throughout the petroleum industry, Wickes boilers are providing dependable, low-cost steam generation . . . for further information on Wickes units, consult your nearest Wickes representative or write for full facts.

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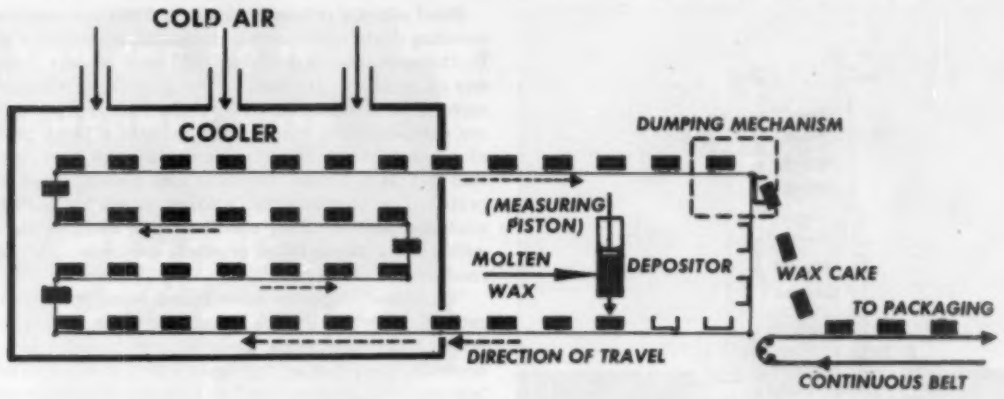


FIG. 2. New system for molding finished waxes.

are drastically refined with chemicals, but those used for technical purposes are sold in the unrefined state.

Asphalt

In oil refineries, asphalt is known as the residue from distilling asphalt-base crude oils. Residues from mixed-base crude oils contain both asphalt and wax and are not suitable for further processing because the presence of wax has an unfavorable effect on the properties of the asphalt from which it cannot be separated commercially. Only in isolated instances, such as for oiling landing fields for airplanes, may admixture of wax with asphalt be beneficial.

Asphalt is used for paving, water-proofing fibrous and porous materials, preparation of paints, and similar purposes. Natural asphalts were considered superior products for many years. Now artificial asphalts made from petroleum are as good or better than the natural asphalts for many applications. Consumption of asphalt is rapidly increasing. In 1924, improved state roads in the United States comprised 9000 miles. In 1940, the bituminous roads had a total length of 200,000 miles, or 40 per cent of all the roads. The rapid growth of the asphalt industry can be seen from the data presented in Table A.

TABLE A. Consumption of asphalt in the United States.

Year	Consumption, bbl	Refinery production, bbl	Per cent supplied by refiners
1910	886,419	886,419	100.0
1914	3,841,585	1,983,757	51.6
1924	15,136,286	5,176,204	33.3
1940	27,182,590	20,455,699	75.3
1952	68,911,007	53,750,587	76.8

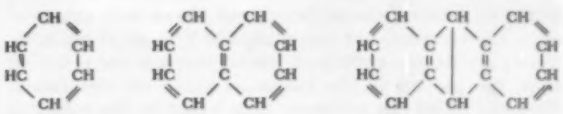
The tabulated data show that more than three-fourths of the asphalt is supplied by the refineries and that for the 42-year period (1910-1952) the refinery production of asphalt increased 60 times. It is still growing at the rate of several million barrels per year.

Commercial asphalts vary widely in their properties depending on their application. Specifications for the different grades usually include softening point, ductility and penetration. Softening point is determined instead of melting point because asphalt does not show an abrupt change between the solid and liquid state on heating. For this reason, the definition of the softening point depends on the procedure employed for measuring it. Different procedures give different results.

Penetration refers to the rate at which a needle pierces asphalt under standard conditions of testing; ductility refers to the ability of asphalt to stretch without breaking. Again the results obtained differ depending on the procedure used.

The major constituents of asphalt are asphaltic substances, resins, and oil. Properties of asphalt depend on the nature and relative quantities of these components present. They are separated like the crude oil components on the basis of their solubility in solvents. The analytical procedures must be followed exactly for obtaining reproducible results because of the absence of sharp demarcation lines between the asphalt components. Different procedures may classify some of the resins as oil or asphaltic substances as resins when the results are compared.

One of the procedures widely used splits asphalt into carboids, carbenes, asphaltenes, resins, and oil. Carboids are insoluble while the rest of these substances are listed in the order of their increased solubilities in organic solvents. Oil present in asphalt is made of complex aromatic molecules. So are the rest of substances present in the asphalt. Their aromatic molecules contain progressively smaller quantities of hydrogen as their solubility in solvents decreases. This happens because the aromatic rings combine as in the example shown below.



C_6H_6
Benzene
-Melts at 42 F
7.74 per cent H
92.26 per cent C

$C_{10}H_8$
Naphthalene
Melts at 176 F
6.71 per cent H
93.29 per cent C

$C_{14}H_{10}$
Anthracene
Melts at 422 F
5.66 per cent H
94.34 per cent C

The rapid rise in melting point of these hydrocarbons with the increase in the number of benzene rings joined to each other is apparent. So is the decrease in their hydrogen content. Asphaltic substances are much more complex than the simple examples shown for illustrative purposes. Their molecules contain many rings of aromatic and other types and structures. Nitrogen, oxygen, and sulfur atoms may be attached to them. The complexity of such molecules is apparent and their exact structure is a mystery. However, if some hydrogen is removed from the oil molecules present in the asphalt, resins are formed. If some hydrogen is removed from the resins, asphaltenes are obtained. In the same way, asphaltenes change into carbons and carbenes into carboids. It is of interest that irrespective how far such reactions go, a small quantity of hydrogen always remains attached to the carbon atoms. On the other hand, if hydrogen is added to the various molecules, the reactions

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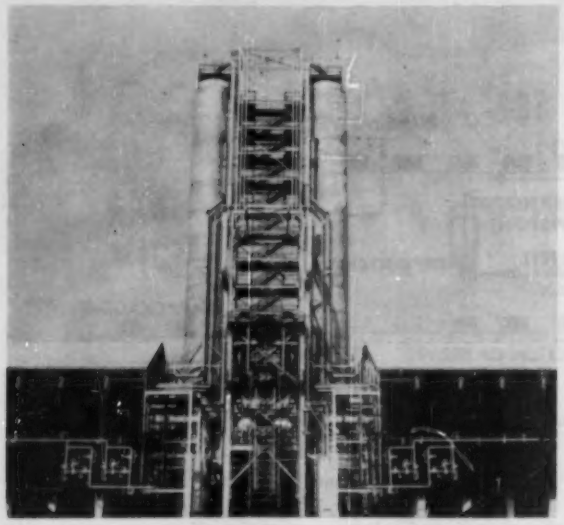

FIG. 3. Double vacuum distillation unit, where lubricating oil fractions are taken overhead and either a long residuum, for making bright stocks (lube component) or asphaltum oil for making asphalt, as bottoms; use of the bottoms depends on the properties of the original crude charged.

go in the opposite direction. Removal of hydrogen from the asphaltic molecules is done commercially by air-blowing at elevated temperatures.

In the preparation of high-grade asphalts, selection of crude oil is of considerable importance. Not every refinery handling asphalt-base crude oils can make good asphalts, and, moreover, considerable caution is necessary in processing them. The oily constituents are separated from the asphalt by distillation, but overheating must be avoided. If asphaltic residues are exposed to extreme temperatures, they may crack, forming coke and low-boiling materials. Presence of these materials has an unfavorable effect on the properties of asphalt.

Asphaltic residues from crude oil distillation are transferred to stills of special design and blown with steam or air at temperatures not exceeding 600 F to avoid cracking. Steam assists in distilling off the oil that was not removed from the asphalt in the course of crude oil distillation. Removal of oil has relatively little effect on the softening point of the asphalt, but improves its penetration and ductility. Air-blowing results in chemical reactions that change the nature of the molecules composing asphalt. These molecules contain carbon and some hydrogen. The larger the proportion of carbon, the higher the melting point of the asphalt. In air-blowing, some, but not all, of the hydrogen is burned off. The resulting molecules contain fewer hydrogen atoms than those that were present before air-blowing. By combining steam and air-blowing, it is thus possible to obtain products of different specifications by employing the same starting material.

Asphalt is made by the batch process. Recently, continuous process was developed, but its acceptance is as yet limited. The difficulty with the continuous processes arises in the necessity of producing a very uniform material fed to the system. In the batch process, variations in the quality of residuum obtained from the refinery stills is corrected by varying the time of steaming and air-blowing.

Attempts have been made to prepare asphalts by introducing sulfur before blowing with air or steam. These attempts, however, are still in the experimental stage and not universally used. The same applies to the addition of other substances for controlling the reactions taking place in air-blowing.

Road oils are related to asphalt. They are employed for covering dusty roads with a minimum expenditure of labor. In the past, the term "road oil" was loosely applied to any oil product sprinkled on the ground for hardening the surface. It is reserved now to the refinery products that are comparatively viscous and contain a large proportion of asphalt. When the oil evaporates, the asphaltic materials act as a binder for sand and gravel. Road oils are prepared as still residue of lower viscosity than the conventional asphalt. They are also made by blending asphalt with gas oil. These latter products are known as "cut-back" road oils or asphalts.

"Colorless" asphalts have found some industrial applications. They are by no means colorless as might be inferred from their name. Their color is considerably lighter, however, than that of the asphalt that is black. The colorless asphalts are employed in mixtures with pigments. The light color of the asphalt is important because it must not interfere with the color of the pigment. Colorless asphalts are obtained by treating crude asphalts with chemicals. Sulfuric acid applied to the asphalt in the presence of propane is a very satisfactory refining agent for this purpose. This treatment removes the darkest-colored bodies from the asphalt. These dark bodies, however, have very high softening points. When they are removed, the softening point of the asphalt is reduced. Colorless asphalts have, for this reason, low softening points, which limits their usefulness.

Greases

Lubricating oils are liquids. This causes occasional inconvenience when they are applied to certain pieces of machinery and results in unnecessary spillage and waste. Solid lubricants are more suitable for some applications than the liquid ones, and methods were developed for solidifying oils without impairing their desirable qualities. Such products are known as greases.

In the past, greases were defined as solutions of soaps in lubricating oils. This definition is no longer correct because many formulas were developed or are under investigation that contain graphite, talc, asbestos, waxes, rosin, fats, pitch and synthetic materials instead of soap. Possibly a better definition for grease is a mixture of lubricating oils with substances that reduce their ability to flow without having an unfavorable effect on the lubrication of mechanisms that they must protect from wear in special types of service.

By far the largest percentage of greases sold on the market are solutions of soaps in oils. The word "soap" in its most widely used meaning signifies the common substance we use daily in order to keep clean. This soap is a chemical compound of an organic acid present in animal fats or vegetable oils and of sodium hydroxide, commonly known as caustic soda. Such a soap is solid at room temperatures. If we want a liquid soap, potassium hydroxide, that is caustic potash, is used instead of caustic soda. In chemistry, soap refers to any combination of organic acids of the above type with any kind of metal. Soaps to which we are accustomed at home represent only a few examples of the broad classification to which the chemical name of "soap" is applied.

The demarcation line between greases and other petroleum products is vague. Some of the lubricating oils contain soaps in the form of addition agents, although the resulting mixtures cannot be considered greases from the practical point of view. The soap content in mineral oils may thus vary from 0.25 to 60 per cent for the products covered by the general definition of greases. But a mineral oil containing 0.25 per cent soap will have none of the semi-solid appearance of a grease.

Materials used in the manufacture of greases include

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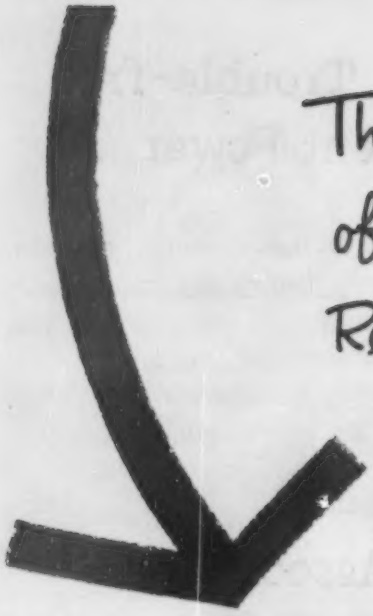

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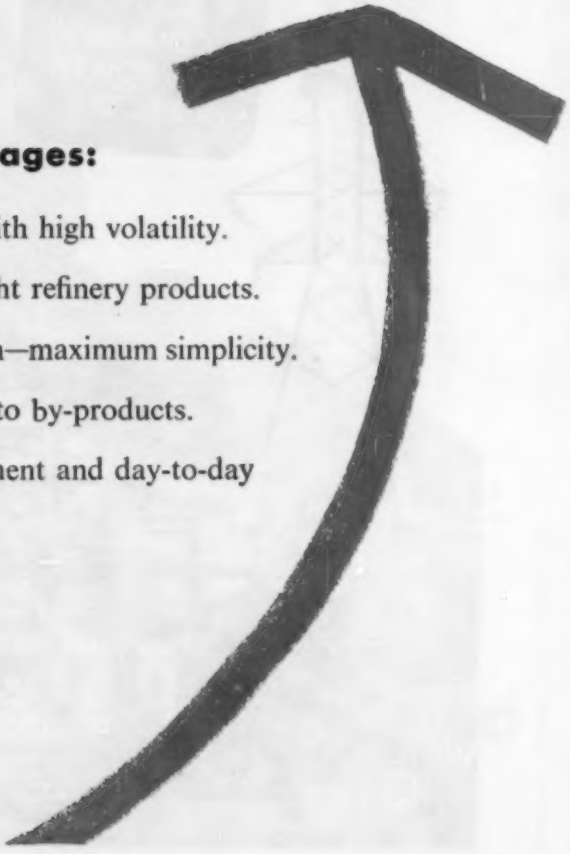

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vegetable and animal oils, fats, and waxes; inorganic basic substances like lime, sodium hydroxide, and similar compounds of aluminum, lead, zinc, barium, magnesium, lithium and potassium; inorganic and organic fillers, like graphite, mica, asbestos, talc, animal hair, sawdust and synthetic materials; perfumed substances and dyes. From this list, it follows that the number of possible combinations used and methods of adding them to the oil approaches infinity. Many of the grease formulas are closely guarded secrets by the manufacturers who developed them at a considerable expense. In these investigations, the empirical approach, that is the cut-and try method, was used. Recently, some progress has been made in scientific studies that will lead eventually to a better understanding of grease-making processes and to the development of new and better products.

Greases are usually manufactured by the batch method. Only in a few instances are continuous processes employed. This is explained by the relatively small quantities of products made by the individual plants and by the difficulties encountered in securing materials of uniform quality. Variations in the properties of raw materials require adjustments during the manufacturing process that are difficult with a continuous system. For many years, grease-making has been considered an art rather than a science.

In preparing a grease, careful attention is given to the time, temperature, degree of mixing, and the order in which the various ingredients are added to the grease kettle. Greases have a colloidal, that is, jelly-like structure. This structure depends on the presence of large clusters of molecules evenly dispersed throughout the product. The size of these clusters and, therefore, characteristics of a grease, change with small deviations from the established manufacturing technique. For instance, by raising the temperature or by increasing the rate of mixing, the size of the colloidal particles decreases and the consistency of the grease approaches that of a fluid although the soap content remains unchanged. Under reverse conditions, dispersion of the soap in the oil is incomplete and lumps appear in the product.

The grease kettles may be open to the air, but in the preparation of certain products closed vessels capable of withstanding considerable pressure are used. Modern equipment, like the one shown in Fig. 4, is quite complicated. It consists of a heater, a high dispersion contactor,

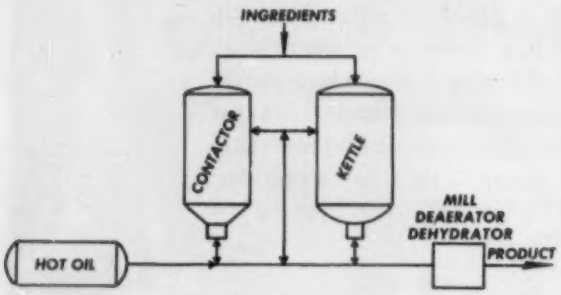

FIG. 4. Diagrammatic illustration of layout of the essential equipment and flowchart of a grease manufacturing unit.

and a kettle. Contactor is used for mixing the grease ingredients before they are charged to the kettle. It can also function as a kettle adding flexibility to the use of the equipment. Before packaging, the grease may be passed through a dehydrator and deaerator for removing traces of moisture and entrained air.

Greases that are sold on the market may be divided into several classes. Lime greases, represented by the so-called "cup greases," contain soaps of calcium. They are water-repellent and are excellent for lubricating mechanisms from which water cannot be eliminated. The "set greases" contain lime and rosin and find application for lubricating rough and slow-moving machinery. Sodium greases contain sodium soaps and are not water-repellent. They have a well-developed "fiber" structure, much superior to that of lime greases. This and other desirable characteristics make them excellent lubricants if water is absent. Greases containing both lime and sodium soaps are also made. Sodium and lime greases comprise by far the larger volume of greases sold on the market. A number of other greases are available for specific applications. The most important of these greases are briefly described below.

Aluminum-base greases contain aluminum oleate or aluminum stearate. Some of them have a rubber-like appearance. They are employed for lubricating special types of machinery, including certain parts of automobiles.

Lithium greases developed during the war are very valuable because they retain their consistency over wide temperature ranges. This is particularly important for lubricating airplanes, and lithium greases are widely used by aircraft. Unfortunately, they are expensive for general applications.

Lead greases contain lead oleate or similar lead compounds. They are widely used for lubricating transmission mechanisms in automobiles. They are often employed in combination with sulfur. Greases containing zinc, barium, magnesium and soaps of other metals than those mentioned, are available for lubricating special machinery, but their consumption is small.

Greases containing no soaps are prepared by blending mineral oils with organic or inorganic fillers and other ingredients. They have a pasty appearance, but, as with any other product, their appearance is not related to performance. These fillers may be also employed in combination with soaps. The word "grease" is loosely applied and covers a wide variety of materials. It refers more to the appearance and "feel" of the substance than to its composition.

Petroleum products used in grease manufacture include lubricating oils, petrolatum and even asphalt. Selection of the mineral oil is important because the lubricating properties of a grease depend on the oil and not on the soap or other materials that are used to keep the oil in place. The source of the oil has an effect on the properties of many greases. For instance, Coastal oils cannot be substituted with Mid-Continent or Pennsylvania oils without changing formulation or manufacturing procedure. However, the problem of selecting greases for different conditions of service is simplified on account of the role played by the oil in the solution of lubricating problems.

Compounded Oils

This is a vague nomenclature, and its significance varies from one plant to another. Originally, compounded oils covered all mineral oils that contained ingredients supplied by other than petroleum industry. The wide use of additives in the majority of petroleum products makes this definition outmoded.

The term "compounded oil" is usually reserved to liquid mixtures of mineral oils with appreciable quantities of animal or vegetable fats and oils. Some of these mixtures are referred to occasionally as "liquid greases," an equally indefinite term. The number of such products is large, and their formulation changes with the service requirements. Practical experience is of much importance in deciding on the composition of the mixture to be used. A thorough knowledge of the properties and effects of individual ingredients is essential for preparing such mixtures.

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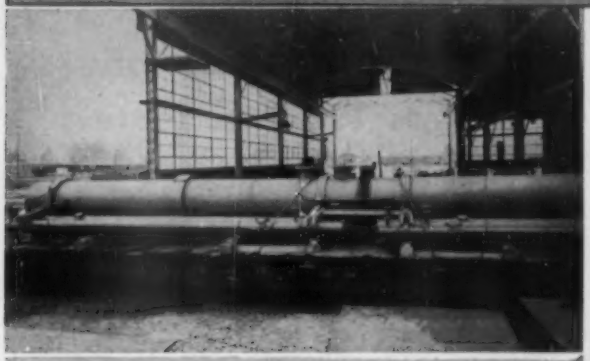

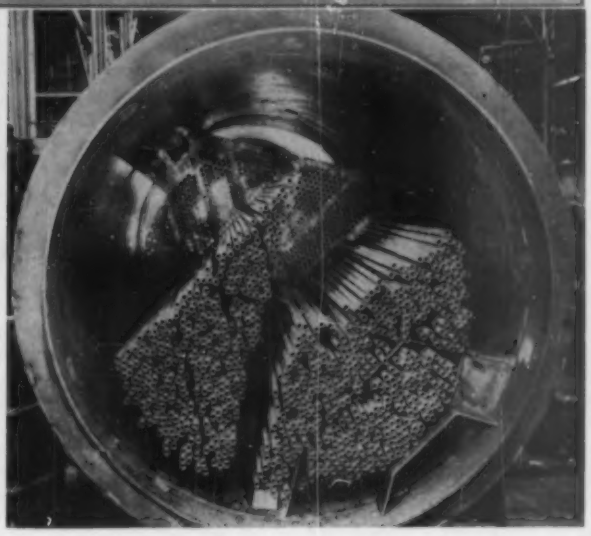

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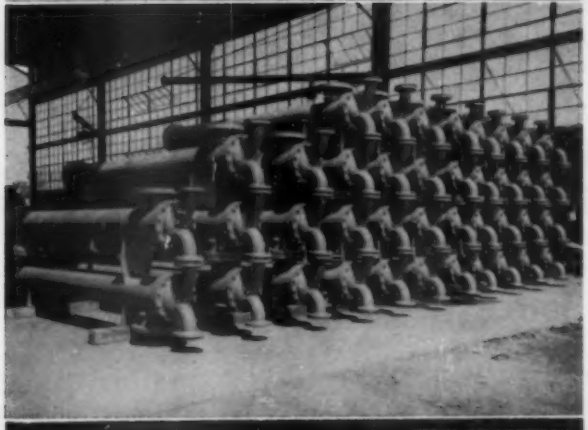

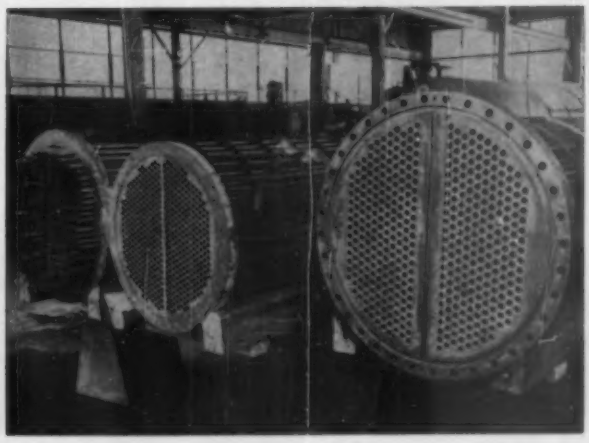

II. SELECTING EQUIPMENT

D. Mechanical Design of Process Tubular Heaters

Section 3

L. A. Mekler
Consulting Engineer

Fuel Oil Burning Equipment

Fuel-oil burning equipment in the fullest sense of the term consists of the means for delivering the fuel to the burners, the burners, the burner blocks, or firing throats, and the means for supplying air for combustion.

Most important variable in the operation of process heaters is the rate of firing required to maintain the desired fluid temperature. Irrespective of the type of burner used, the firing rate cannot be properly controlled if the fuel supplied to the burners varies abruptly in composition, calorific value, pressure on the upstream of the regulating valves of the burners and, with liquid fuels, temperature and viscosity of the fuel.

Process heaters are fired with gaseous fuels, liquid fuels and a combination of both. The gaseous fuels may be natural gas, a mixture of natural gas and tail gases from different processes, or tail gases alone. With natural gas alone, there is no problem in supplying the heater with fuel of uniform quality at constant pressure. Two basic schemes can be used to control the total gas supply to the header of a heater. In one scheme, the total supply is controlled by a pressure regulator actuated by the pressure in the header. This is the simpler of the two schemes and all that is required with natural gas and an adequate supply of gas at a constant pressure on the plant main. Where the main is too small and the pressure in the main drops with increase in total demand, the second scheme with a flow controller on the gas header will give better control than a pressure controller.

Where the fuel gas is a mixture of tail gases from different processes, which vary in total and relative quantity and in composition, or where the mixture changes radically in composition when one of the processes is off stream, the fuel gas supplied to the heater may vary sufficiently to affect the operation of the heater, particularly if the tail gases are burned alone or represent the major portion of the fuel gas. To dampen the variations, most plants use a mixing or "time" tank where all the constituents of the fuel gas are mixed before they enter the gas main. The mixing tank is made large enough to hold a 5-15 min supply of fuel, the wider the variations the larger the tank. When the tail gases are augmented with the natural gas, the natural gas is pre-mixed with the tail gases in the mixing tank.

Where a mixture of tail gases alone is burned and the total quantity of the tail gases is not sufficient to meet the requirements of all fuel-consuming units at all times, the fuel gas distributing system is usually arranged to give priority to those heaters where gas firing is most desirable. Fig. 9 shows a schematic arrangement of a sequence of three priorities with the surplus going to the torch. The pressures shown on the scheme are intended to indicate the minimum desirable pressure differences between the branches rather than the actual recommended pressures. The dotted lines indicate how natural gas and C_3 and C_4 can be used to augment the tail gases in the fuel gas mixture. In some plants, where the tail gases consist primarily of hydrogen and are insufficient to meet the fuel requirements, and where C_3 and C_4 sell at about their equivalent price of fuel oil, definite quantities of C_3 and C_4 are added to the tail gases to obtain a mixture that can be burned in standard gas burners with substantially the same flame characteristics and fuel-air ratios as natural gas or mixtures of natural gas with the higher hydrocarbon gases.

In many plants, particularly in oil refineries, the liquid fuel is a mixture of standard fuel as produced for the market, surplus products, slops, bad batches, etc., so that the fuel oil as actually burned is composed of constituents that may vary considerably in calorific value, viscosity and ignition and burning characteristics. In most plants, the proportion and composition of the various constituents of a mixed fuel oil are relatively constant from day to day, so

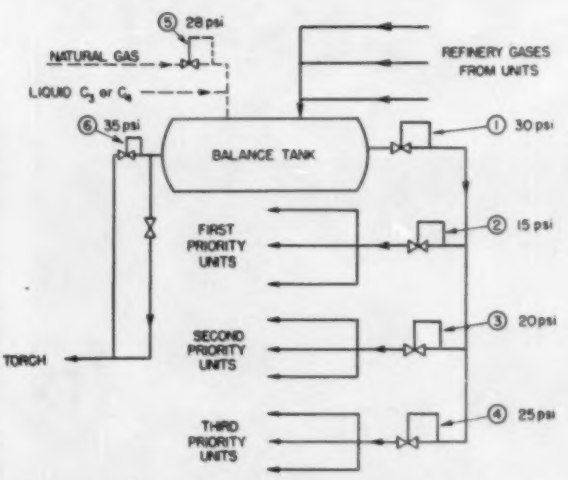

FIG. 9. Schematic arrangement of priority sequence for gas firing.

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	$ Saving	% Saving	$ Saving	% Saving	$ Saving	% Saving
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Du Pont Fuel Oil Additive No. 2	$1,680	8.3%	$1,710	8.4%	$1,850	8.9%
Du Pont Lube Oil Additives	$1,830	12.0%	$1,860	12.0%	$2,000	12.5%

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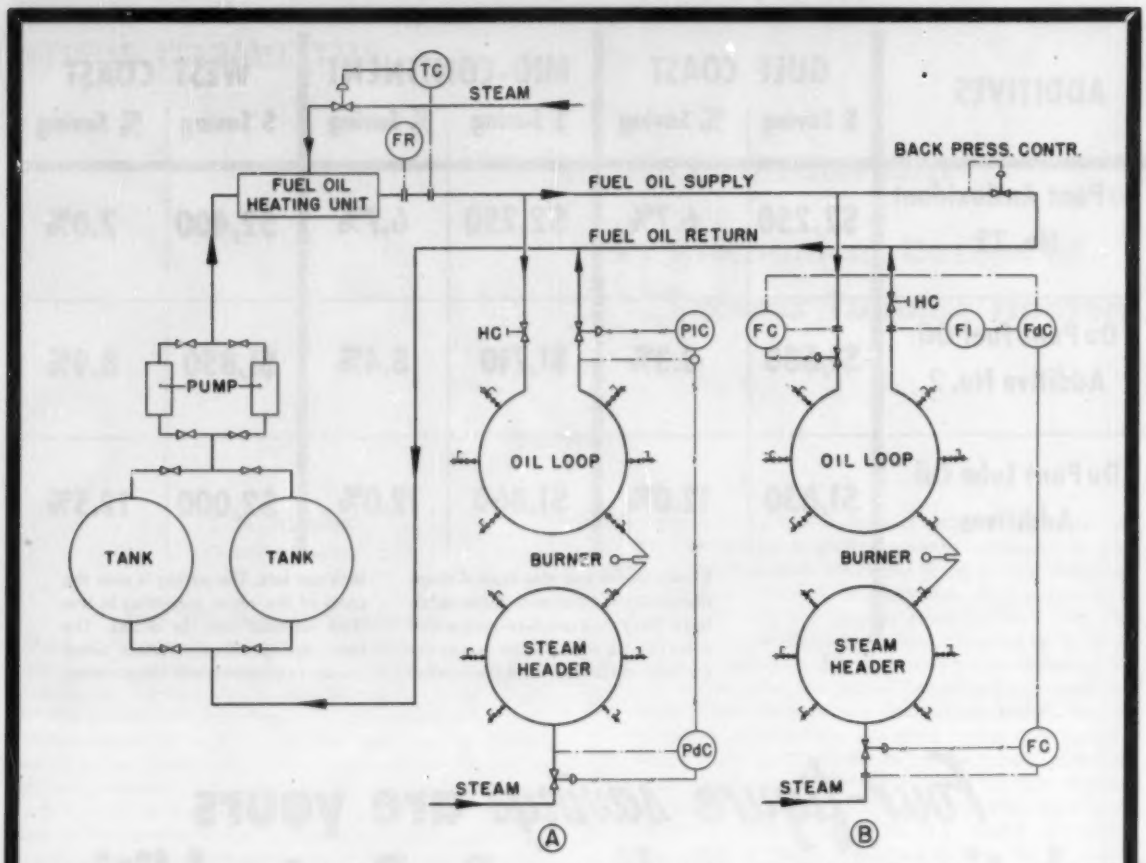

FIG. 10. Schematic arrangement of parallel fuel oil circulating system and hook-up for proportion atomizing steam and oil. (A) Control by pressure; (B) control by flow.

that, if properly mixed, they will produce a fuel oil of substantially uniform composition which can be handled as if the fuel were a special commercial grade.

For proper operation of fuel oil burners, the fuel must be supplied to the burners at a constant pressure and a constant temperature that will give the optimum viscosity for the proper atomization of the fuel, which, depending on the fuel and on the burners, may vary from 50 to 200 SSU. The fuel oil supply system must also be so arranged that it is not affected by variations in demand of other fuel-consuming units on the system.

Fig. 10 shows a schematic arrangement of a parallel fuel-oil circulating system arranged to meet these requirements. The two service tanks are used alternately—one as a mixing and blending tank, and the other as a supply tank. Each tank preferably has a capacity sufficient to hold at least as many days supply of fuel used in the system as is required to average the quality of the fuel with the regular day-to-day variations in quantity and quality of the constituents of the fuel mixture. If these require too large a tank, a blending tank holding at least a day's supply of fuel will average out the daily variations and assure steady operation during each day. The blending is accomplished either by agitation in the tank by blowing or mixers, preferably the latter, or by recirculation through mixing nozzles. Unless the constituents of the fuel are thoroughly mixed in the blending tank, they may produce a "layer cake effect," with the fuel supplied to the burners changing as each layer reaches the pumps.

The fuel-oil heating unit may be a central installation for the whole system as shown on the scheme, or each fuel-consuming unit may have individual fuel-oil heaters, particularly when the system supplies a number of units spaced a considerable distance apart so that even with good insulation on the supply header, there may be an appreciable drop in fuel temperature from one unit to another. With individual heaters at each unit, the fuel is preheated in the service tank to at least a temperature that will permit pumping the fuel through the system without excessive pressure drop due to high viscosity.

The circulating system on Fig. 10 shows two fuel-consuming units connected to the system, but the arrangement can be applied to any number of units. The supply header on the system is maintained at a constant pressure of 80-150 psi for steam atomizing burners and 150-300 psi for mechanical atomizing burners. The pressure on the return header is just sufficient to overcome the pressure drop through the header. Generally, a flow meter is installed on the supply header to keep the flow through the system 3 to 4 times the amount consumed by the units. The loop of each unit is connected to the supply header on one end and to the return header on the other. The flow through each loop is 2 to 3 times the consumption by the unit.

For proper operation of steam atomizing oil burners, the fuel oil must be properly atomized, which can be done only with dry steam maintained at a temperature higher than that of the fuel. This is particularly important with asphalt-like fuels that are often preheated to temperatures

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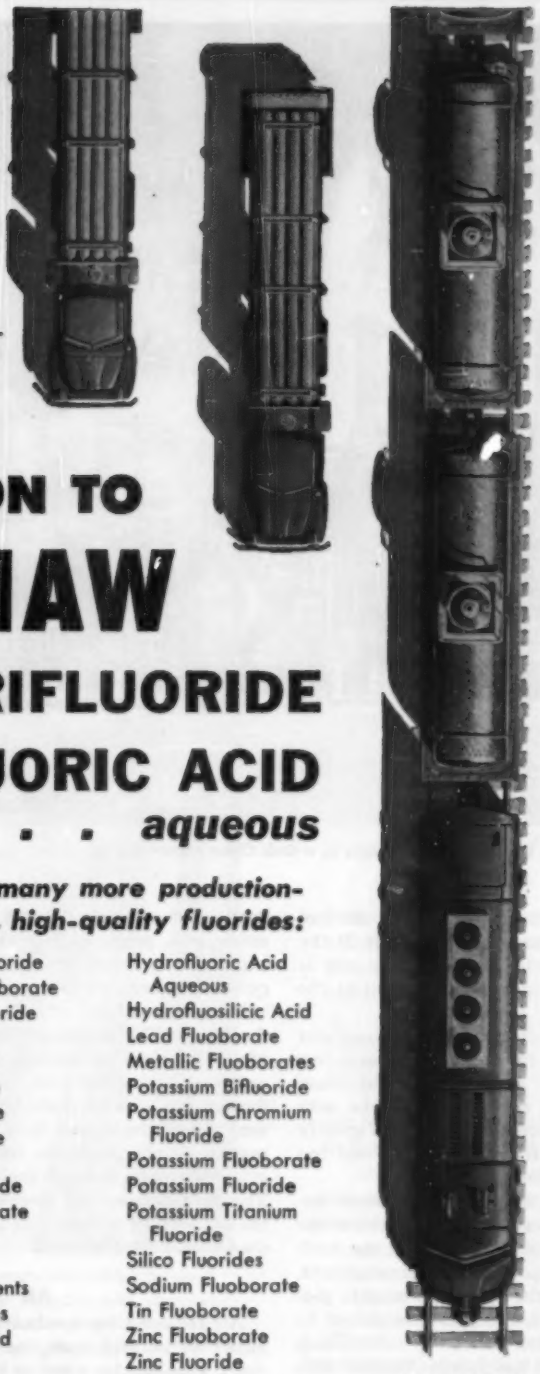

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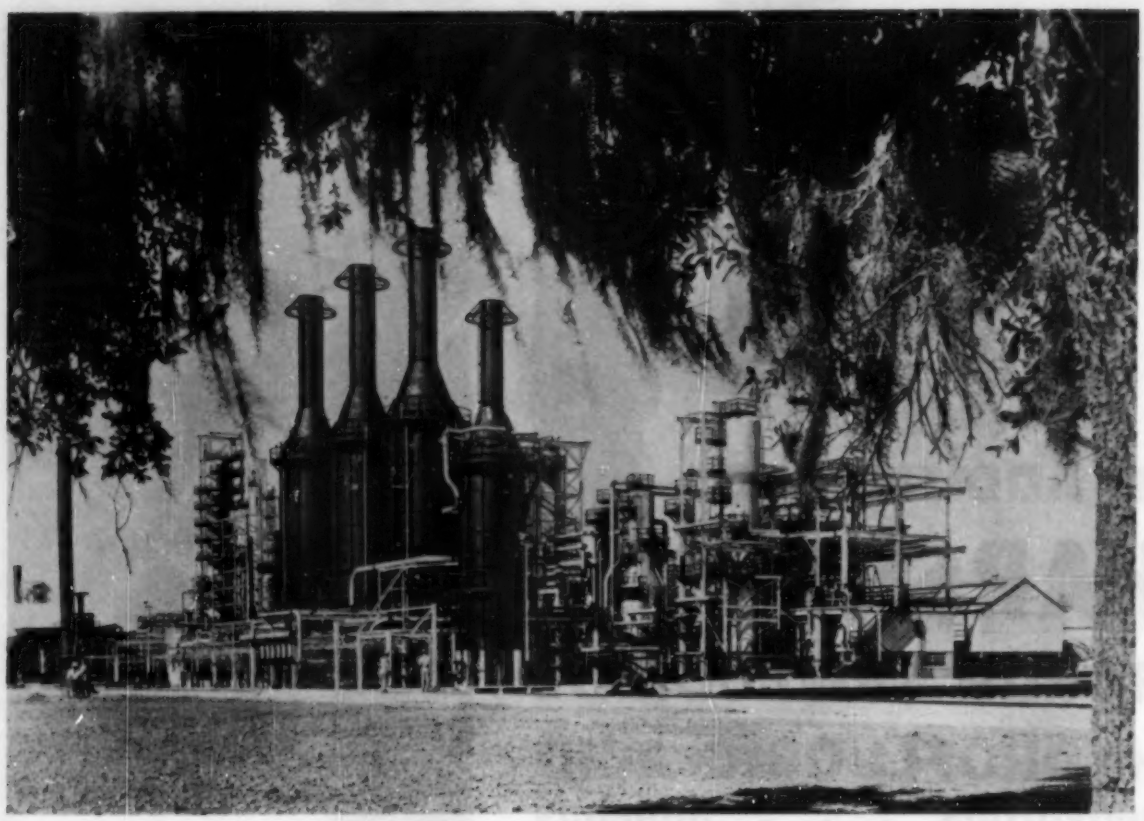

Petrochem-type heaters in a Gulf Coast lubricating oil plant.

up to 500 F. Steam colder than the fuel may chill the fuel and make its atomization that much more difficult. If the steam is only a few degrees hotter than the fuel and is saturated, the steam may be condensed by the oil at the tip, and hot water is a very poor atomizing agent.

To maintain the desired flame characteristics throughout the required range of firing rates, the degree of atomization must be the same throughout the range. Insufficient steam will produce "fireflies" and long smoky flames even with large amount of excess air. An excess of steam will greatly shorten the flames and reduce their emissivity, and too much steam may blow out the fires.

Scheme 10A shows an interlocking arrangement between the fuel-oil loop and the steam header where the pressure on the steam header is controlled by the back pressure regulator on the oil loop. With this arrangement, the amount of steam supplied to the burners is roughly proportional to the amount of fuel burned, as determined by the pressure of the oil loop. A more accurate relationship between the atomizing steam and the fuel is obtained with Scheme 10B, where the flow of the steam is controlled by the flow of fuel as determined by a differential flow controller on the oil loop. Both schemes can be used for automatic firing, with the temperature controller actuating the pressure regulator on the oil loop in Scheme 10A and the flow controller on the loop in Scheme 10B.

The circulating system shown on Fig. 10 is applicable primarily to fuel-oil mixtures of normal viscosity and pour point. In recent years, a number of oil refineries burn pitch-like residues such as bottoms from vacuum units or asphalt from deasphalting units. With these residues, the circulating system must be arranged so that the residues will not solidify in the lines. With pitch-like fuels, all lines up to the burner are jacketed and heated either by superheated steam at a pressure that will produce a condensate at a higher temperature than the minimum temperature required for free flow of the residue, or, preferably, by a circulating liquid heat carrier, such as re-cycle gas oil, Dowtherm, etc. The circulating system is also so arranged that when the fuel consuming unit is taken off stream or switched to regular fuel, the oil loop can be drained or flushed out without disturbing the other loops on the system. When the heater is to be fired alternately with the regular or the pitch-like fuels, it is equipped with a circulating system for each fuel interconnected at the burners. The arrangement for interlocking the steam header and the oil loop of a heater as shown on Fig. 10 can also be used with pitch-like fuels.

Air Supply

Air required for combustion is supplied to the burners either by natural draft, induced by a stack, or by forced draft, supplied by a fan or blower. With natural draft, the stack must overcome the resistance to the flow of air through the burner and the resistance to the flow of products of combustion from the burner to the top of the stack.

The static draft, or the gross draft at the base of the stack, can be calculated from the following simple relationship.

$h = 19.2\ (D_a - D_g)$ where

h = static draft in inches of water per 100 ft height of stack

D_a = density of atmospheric air, lb/cu ft

D_g = density of stack gases at the *average effective* temperature of the gas, lb/cu ft

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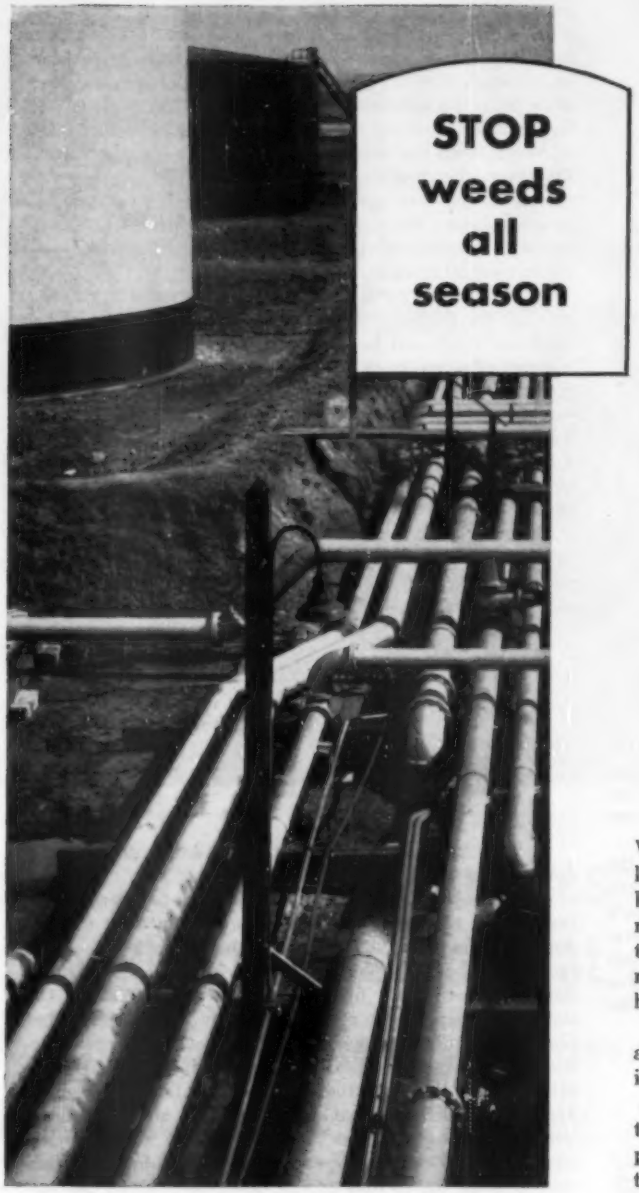

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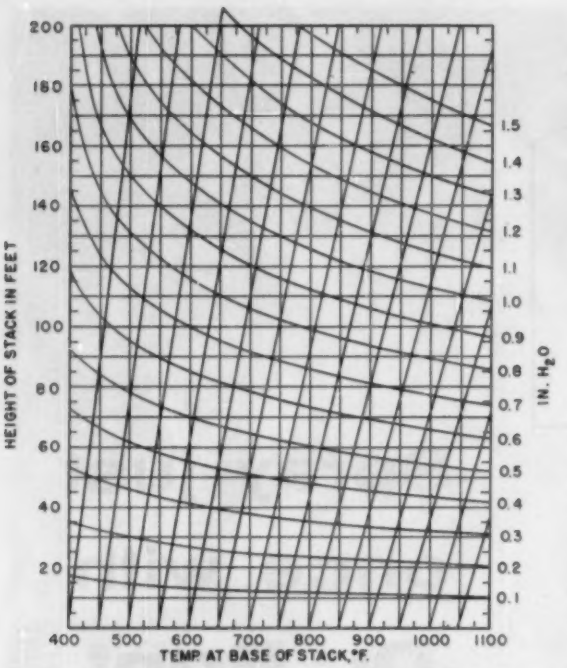

FIG. 11. Relationship between temperature at base, effective temperature and draft with unlined steel stacks. (Courtesy UOP).

Average effective temperature of the gases is the mean between the temperature at the base of the stack and at the top of the stack. The gas temperature at the top of the stack is lower than at the base because of radiation losses through the stack.

With uninsulated steel stacks, the radiation through the stack is large enough to be taken in consideration when determining the average effective temperature of the stack gases. Fig. 10 shows the relationship between the temperature at the base of the stack, the height of the stack, the effective temperature of the stack gases, and the effective draft produced by the stack. The following example shows the use of Fig. 11 to obtain these relations.

Temperature at the base of the stack, 800 F
Height of the stack, 120 ft

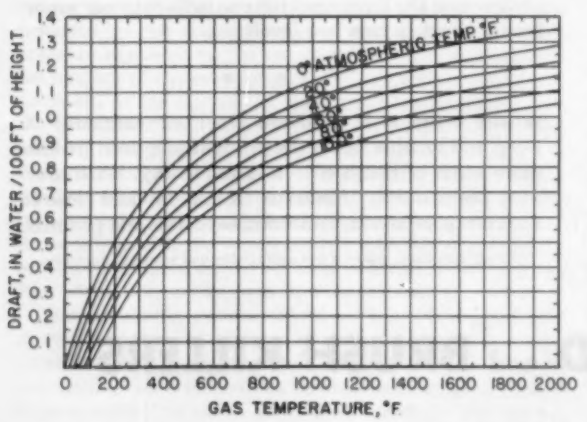

FIG. 12. Stack draft with different atmospheric temperatures. (Courtesy UOP).

To obtain the effective temperature of the stack, follow the vertical 800 F temperature line to intersection with horizontal 120-ft height line. From the intersection, draw a line parallel to the nearest inclined straight line downwards to the temperature scale. The average effective temperature of the stack is 680 F. To obtain the available stack draft, draw from the intersection a line to the draft scale following the nearest curved line. The answer is $0.78 \times 1.2 = 0.95$ in. W. G. With the uncorrected temperature at the base of the stack, the draft would have been 1.1 in., or approximately 20 per cent too high. With insulated steel, brick or concrete stacks, the radiation losses are considerably lower but still appreciable and must be taken into account with stacks over 80 ft high.

Values shown on Fig. 11 are for an atmospheric temperature of 80 F. For other atmospheric temperatures, the available draft can be obtained from Fig. 12, using the average effective stack temperature as the temperature of the gases. From this figure with an effective stack temperature of 680 F, the available draft will be approximately 0.85 in. W. G. and with an atmospheric temperature of 20 F, 1.10 in. With an increase in elevation above sea level, the available stack draft decreases, while the volume of the gases increases. To correct for elevation, the height of the stack is increased by a factor of $1 + R^2$, while the diameter, by a factor of $1 + R^{2/3}$, where R is the ratio of density of air at sea level to that at the elevation. The correction factors are approximately as follows:

Elevation	*Height*	*Diameter*
Sea Level	1.0	1.0
2000 ft	1.16	1.03
4000 ft	1.36	1.06
6000 ft	1.58	1.10
8000 ft	1.84	1.13

Another cause of reducing the available draft is the downflow of atmospheric air into the stack.

A stack of a given height with a given temperature at the base of the stack will produce a certain draft that induces a definite gas velocity through the stack. When the induced velocity is higher than the velocity at which the flowing gases would fill the cross-sectional area of the stack, the main stream of gases will flow only through that portion of the core of the stack which would give the velocity produced by the draft. The peripheral area outside the filled core of the stack thus becomes a relatively stagnant zone, into which the heavier atmospheric air can pour in over the top of the stack. The air diffuses into the main stream as it flows down and eventually joins the main stream going up, so that eddies, downwards along the surface of the stack and upwards along the edge of the high-velocity core, fill the space between the wall of the stack and the high-velocity core. The eddies if not excessive do no harm. With excessively oversized stacks placed above the convection section, the downflow may extend into the convection section and reduce the MLTD and the rates in the section.

Generally, the optimum diameter of the stack is that which will give a mass velocity between 0.8 and 1.2 lb/sec/sq ft, depending on stack gas temperature, with 70-80 per cent of the available draft at the base of the stack. The remaining 20-30 per cent of the available draft is to compensate for friction losses through the stack. A stack with a too small diameter may cause a high friction loss through the stack, and, in extreme cases of inadequate stack area, the friction loss may be so high that increasing the height of the stack may reduce rather than increase the available draft.

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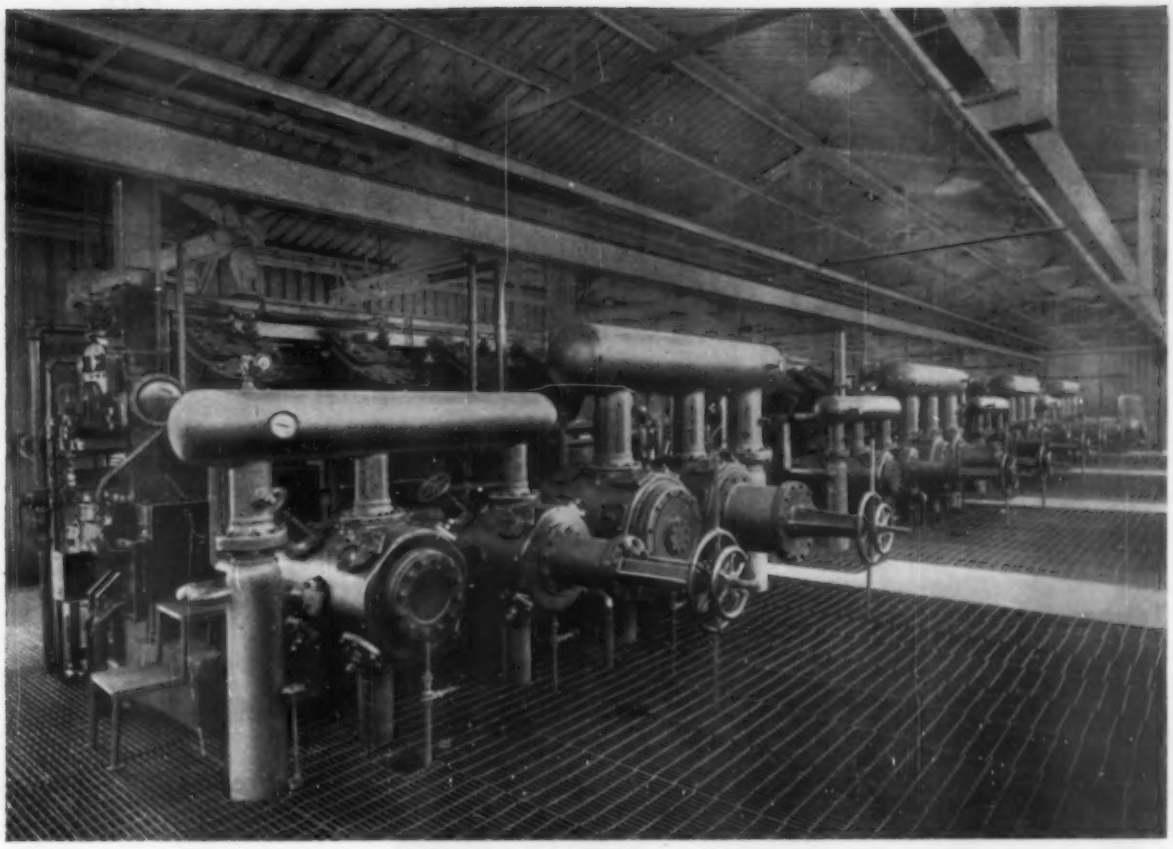


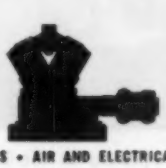
SVG gas-engine compressors maintain critical pressures on cat-cracker gas recovery

for National Cooperative Refinery Association

Gas recovery compressors in a catalytic cracking plant must hold constant suction and discharge pressures – a job made difficult by widely-fluctuating volumes flowing through the plant. This problem was solved for the National Cooperative Refinery Association at McPherson, Kansas, by Ingersoll-Rand engineers and SVG gas-engine compressors.

Ingersoll-Rand provided a special control system which keeps suction pressure constant by a choice of several methods, depending on plant conditions. SVG compressors are particularly suitable for such service because of the smooth operation and flexibility of I-R 4-cycle design. Regardless of speed or load, smooth power is maintained automatically by the constant-quality mixing valve. And the famed Ingersoll-Rand reliability is important in a year-round continuous-flow system like this, where compressor failure cannot be tolerated.

Ingersoll-Rand gas-engine compressors are built in sizes from 110 to 2000 hp, for any gas, any pressure. If you have a compressor problem, call your nearby I-R representative. He is always ready to give valuable help.



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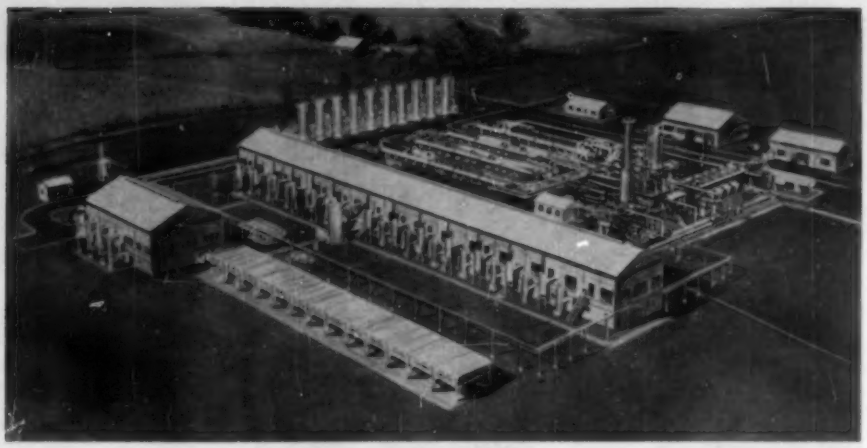


FIG. 1. Architect's view of the Greensburg, Kentucky, gasoline recovery unit.

Tennessee Gas Transmission Company Proves Process for

Low-Temperature Gasoline Extraction

Investment cost of this plant is about half that of an absorption plant; operating cost is considerably below conventional plant

R. V. Mertz
Vice President
Petro-Tex Chemical Corporation

THE largest gas capacity ever designed for a plant processing natural gas was put into operation by Tennessee Gas Transmission Company near Greensburg, Kentucky, in late 1951. Initial capacity was 750,000,000 cu ft of pipe line gas per day. In April, 1954, the capacity was further increased to 950,000,000 cu ft per day. Liquids previously found objectionable to Tennessee's gas customers are condensed and delivered to a chemical company, which converts them to ethane, LPG, and natural gasoline. Total liquid production is 440,000 gal daily with a maximum of 475,000 gal.

Gas entering the plant from the pipe line must be dried before being subjected to low-temperature processing. Sixteen dehydrators operating in parallel are required to handle the total feed gas flow.

Dry gas from the dehydrators at 70 F is cooled to -104 F at 535 psi. Under these conditions about 5.5 mol per cent

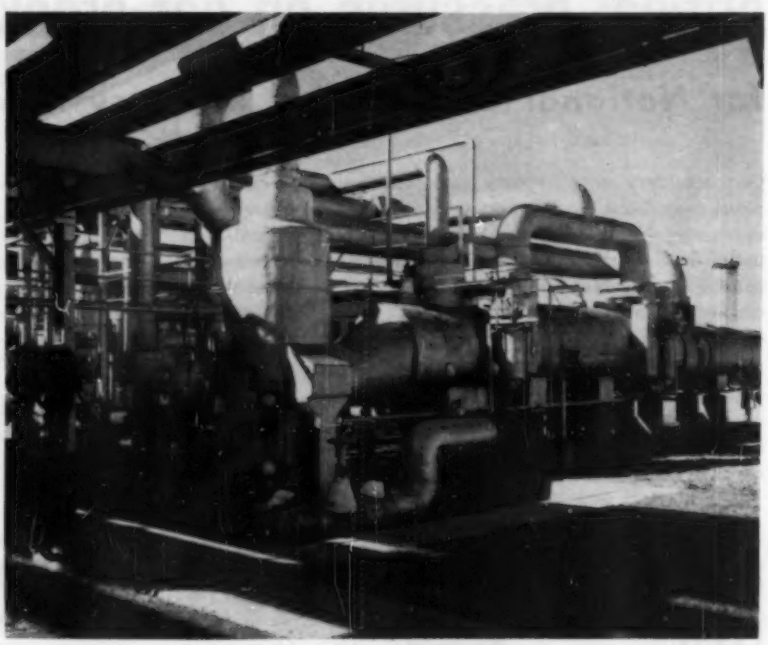


FIG. 2. View of "B" train piping at the Greensburg plant.

Condensed by the author from a paper presented at the ASME Petroleum Mechanical Engineering Conference in New Orleans, Louisiana, September 25-28, 1955.

PETROLEUM CHEMICALS DIVISION
NEWS

June ★ One of a Series of Bulletins for the Petroleum Industry ★ 1956

In This Issue . . .

1. YOU'LL BE INTERESTED in the new dry-dye eduction probe developed by Du Pont. It's described at the right.
2. HOW CAN *YOU* use the Du Pont automotive service discussed below to promote better relations with your large commercial fleet customers?
3. IF YOU HAVE a refinery in the Chicago area, you'll want to know Dr. Neal Lawson and how he can help you make the most efficient use of additives. See next page.
4. THE MOVIE is one of the most valuable of modern sales promotion and training tools. There's an article on the next page about four Du Pont movies produced to help you in your sales, training, and public relations.

They can help you turn complaints into sales

Our Du Pont automotive specialists have more than just faith in the high quality of your fuels and lubricants. They're always prepared to help you *prove* your quality story.

For example . . .

The operator of a fleet of tractors and other gasoline-powered farm equipment, complained about excessive valve burning. He was quite emphatic about blaming the trouble on fuel quality. And he had practically made up his mind to change suppliers when the oil company representative, accompanied by a Du Pont automotive specialist, arrived on the scene to investigate the trouble.

An impartial third party, the Du Pont man was able to convince the rancher that the fuel was not the real source of the trouble . . . but rather that it was the result of tractor operators tinkering with the air-fuel mixture ratio.

This is only one of many cases in which oil companies have been able to turn complaints into good will with the help of a Du Pont automotive specialist.

Our men often accomplish this through the use of the Du Pont fleet of fuel test cars, our single-cylinder demonstration engines and chassis dynamometers – in addition to their own wide experience in solving automotive problems involving the use of fuels and lubricants.

The services of these Du Pont automotive specialists are yours for the asking. And you can get in touch with one of them through any of our sales offices listed in the signature of this ad.

Faster, cleaner, easier gasoline dyeing now possible with new eduction development

A revolutionary new dry-dye eduction probe, developed by Du Pont engineers, can make gasoline dyeing a cleaner, faster and more efficient operation. The device, although simple in design, offers six distinct advantages over other gasoline-dyeing methods . . .

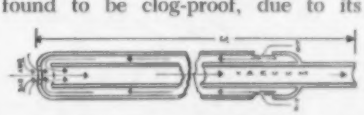
HERE IS a typical setup for using the new Du Pont Dry-Dye Eduction Probe. A short neoprene hose makes possible a permanent, yet completely flexible coupling.

1. "Dusting" is reduced. Exposure of operator and area to dye is minimized. Cleanup time is saved.
2. No plugging of the probe, hence no interruption of the dyeing process. No time loss for clearing plugged probe, and cleanup of area afterward.
3. Dye from the shipping drum can be introduced directly into the finished gasoline. Thus the step of pre-dissolving, required by some systems, is eliminated.
4. Minimum of operating skill required.
5. More pounds of dye are transferred per minute.
6. Minimum investment in space and equipment, considering the cleanliness of operation achieved.

Design and Operation

Conventional probes are little more than pipe sections, some with modified tips. Dipped into the drum, these probes suck up dry dye and pass it into the gasoline system. They are relatively inefficient, however. Extreme care is required of the operator – yet clogging is still likely to occur from time to time. This means interruption of the dyeing process – both to clear the probe and to clean up the area.

In many field tests and under varied conditions, the new probe has been found to be clog-proof, due to its



unique design. It is an aluminum tube within a larger one. The inner tube,

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OVER

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CONTINUED *Eduction Development*

like the earlier probe itself, transfers the dye from drum to main system. However, the outer tube supplies a down-draft of air, controlled by two adjustable ports at the head end, which insures continuously fluidized flow of dry dye that is uninterrupted by clogging. This feature is an important time-saver.

Dyeing Speed

The new eduction probe makes possible faster dyeing. Tests in units currently in use show speeds ranging from 18 pounds per minute for Du Pont Oil Orange to 40 for Du Pont Oil Red.

The Complete Eduction System

The principal factors responsible for the successful operation of a complete dry-dye eduction system are:

1. Adequate air handling capacity
2. Proper suction-line design
3. The probe described above

A smooth line from the mouth of the probe to the eductor is essential to avoid plugging. The dye probe should be permanently coupled to a short length of neoprene hose. The entire line from the mouth of the probe to the eductor should be of 1-inch inner diameter and completely unobstructed. It should be as short as possible, preferably not over 10 feet. The shut-off valve employed should be of a type permitting full-round flow. Pressure gages guide the operator.

Eduction systems can be used to transfer other fine crystalline materials as well as dry dyes; for example, Du Pont Gasoline Antioxidant No. 29.

However, for the transfer of *liquids* – such as Du Pont Metal Deactivator and Gasoline Antioxidants Nos. 5 and 22 – a separate eduction system should be used. Use of the same system, first for a liquid, then for a dry product, might result in clogging caused by residual liquid in the line.

Low-cost Installation

Your present dyeing facilities can probably be modified to utilize the features of this system at relatively low cost. A Du Pont Petroleum Chemicals Division representative will be glad to study your present system and make appropriate recommendations.

REGIONAL ADDITIVES SALES MANAGER

DR. NEAL D. LAWSON was recently appointed to the newly created post of Additives Sales Manager of the Du Pont Petroleum Chemicals Division's Central Region.

With headquarters in the Chicago office, he is in charge of sales and technical service work for all Du Pont additives other than tetraethyl lead. This includes Du Pont Metal Deactivator, lube and fuel oil additives, antioxidants, dyes, and grease stabilizers.

Prior to this assignment, Dr. Lawson was head of the chemical division of the Du Pont Petroleum Laboratory. He had previously been supervisor of the Laboratory's lube oil group.

Before joining the Du Pont Company in 1947, he was Research Assistant and Instructor in Petroleum Refining at Pennsylvania State University. His work there included research on the oxidation of lube oils, the influence of refining procedures on oxidation, and development of additives for lube oils.

Dr. Lawson is a chemical engineering graduate of Pennsylvania State College, where he also received his M.S. and Ph.D. degrees. He is a member of the American Chemical Society and Society of Automotive Engineers.

These Du Pont movies help promote your on-the-move industry

During recent years, audiences estimated at well over a million people have seen these four Du Pont-sponsored movies promoting your industry.

What Makes a Gasoline Good, a full-color cartoon movie, explains graphically and convincingly how refiners tailor gasoline quality to motorists' needs. Since the film's release, the Du Pont Petroleum Chemicals Division has made available to oil companies a total of 249 prints.

Pipeline on Wheels shows how gasoline tank trucks are made and operated for maximum highway safety. One hundred and seventy-five prints of this film have been made available for oil industry use. For 52 of them which were purchased and distributed directly by oil companies, we have no audience records. But the remainder, distributed by Du Pont on a loan basis, were seen by more than 61,000 people.

A total of 395 prints were made of the Du Pont movie, **It Never Rains Oil,** which tells the story of percentage depletion. Reports indicate that this film is doing an excellent job of creating a better understanding of this important issue.

The newest movie in the series is entitled, **When the Customer says "KNOCK."** It explains – for the benefit of service station operators and customer groups – the many mechanical and atmospheric factors (other than gasoline quality) which contribute to knock.

Prints of these films are readily available to you on a loan or purchase basis. Address your request to any of our sales offices listed below.

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A-2071

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of the gas condenses. The condensed hydrocarbon liquid is separated, and the residual gas, after heat exchange, is compressed to 590 psi and returned to the pipe line.

Five parallel trains of heat exchangers are required for feed gas cooling. the first four shells in each train exchange heat between the incoming warm feed gas and the cold residue gas stream from which the condensed hydrocarbon liquid has been removed. The fifth shell employs ethane refrigerant at -96 F to furnish the net refrigerating effect required to remove latent heat from the liquid product. The last shell in line recovers refrigeration by evaporating excess light hydrocarbons, principally methane, which were condensed in the high-pressure separator.

The hydrocarbon liquid collected in the liquid separator is flashed to a lower pressure. The vapor-liquid stream is warmed by heat exchange with the feed; the liquid is separated and flows to the second feed flash operation while the disengaged vapor, after further heat exchange, is compressed and returned to the pipe line.

This series of operations is designed to reduce the methane content of the hydrocarbon liquid condensed from the feed gas. The liquid is flashed and heated under conditions which are favorable to the preferential vaporization of methane and which also make possible the recovery of valuable low-temperature refrigeration.

Liquid from the first flash exchanger is flashed to a lower pressure. The residual liquid from the flash is separated from the vapor and is forwarded to the fractionator while the vapor, after heat exchange, is used for plant fuel.

The fractionator produces a bottoms liquid product of desired specifications that is cooled and then flows from the plant to the product line. Tower overhead vapor, after heat exchange, is compressed for return to the gas pipe line.

The residue gas stream, the first flash vapor stream, and the fractionator overhead must be compressed for return to the pipe line.

Refrigeration

A conventional ethane-propane, cascade-type refrigeration system is employed in this plant to provide low-

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ALL fires are costly — in property damage, in lowered employee morale, in interrupted production. And the best way to fight a fire is not to let it start. That's why a small investment pays off in real fire protection, when you provide Ampco Safety Tools for use in hazardous locations.

Ampco Safety Tools are approved and recommended by Factory Mutual Laboratories and other leading safety authorities for use wherever there's a special fire hazard — spray booths, paint lockers, gasoline-storage areas, etc.

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level ethane refrigeration at -96 F and intermediate level propane refrigeration at -15 F. Under this system, ethane refrigerant is circulated in a closed system and condensed with propane refrigerant, which also circulates in a closed system, and in turn, is condensed with cooling water.

The ethane is vaporized at 19.7 psig and -96 F in the feed gas coolers. The vapor is compressed through two stages to 200 psig. It is condensed at -5 F in the main ethane condensers and returned to the storage tank. thus completing the ethane refrigeration cycle.

In the propane refrigeration cycle, liquid propane flows into the interstage flash drum.

Vapor is taken directly into the second stage suction of the propane compressors.

Propane liquid from the interstage flash drum flows into the shell side of the ethane condensers, the deethanizer condenser, and the make-up tower units at -15 F and 13.3 psig flows condenser. Propane vaporized in these through the propane suction separator into the low-stage compressor cylinders. It is compressed in two stages to 200 psig.

The high-pressure propane vapor is condensed in water-cooled propane condensers and then flows into the propane storage drum.

Mechanical Design Features

The low temperatures involved in the plant created special problems in the mechanical design. Alloy steels were needed for all temperatures below -20 F.

Almost any good insulating material was believed to be satisfactory but required special application techniques. Asphalt was used to seal all joints. No trouble has been experienced with this part of the plant except where the sealing has been disturbed. In such cases, it is necessary to warm the equipment and dry out the insulation or to replace that part which has become wet.

Dehydration

When it is necessary to produce a -104 F dew-point gas, the problem of dehydration is quite difficult. The dehydrators were designed to absorb only 3 per cent by weight of water based on the desiccant charge. To insure continuous operation, however, a methanol injection system was installed so that minor freeze-ups could be cleared. In addition, it was planned that the heat-exchanger trains would be taken out of service periodically for warming and thawing.

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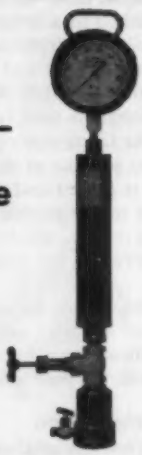
for testing Natural Gasoline – Benzol Blends – and other liquids not exceeding a vapor pressure of 45 lbs. at 100° F. by the Reid Method.

Construction conforms strictly to A.S.T.M. specifications. Requires no wrench—By means of the "O" ring gasket hand coupling will make a tight seal. Each bomb tested for 200 pounds air pressure.



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- **Studies of efficiency of drying systems.**
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Most troublesome lubricating problem has been with the removal of the oil from the refrigerant streams. If the oil is not removed, it travels with the vapor and is condensed along with the refrigerant. When the refrigerant is used in the cooling process, the oil carried along increases in concentration in the vessels and exchangers. An increase in oil content raises the boiling point of the liquid and lower pressures must be used to obtain the desired temperature. In addition, the wax content of the oil builds up on the cold surfaces. The equipment must be taken out of service and warmed with hot gas to remove the wax deposits.

Operating Results

The overall operation has been very satisfactory. There has been very little downtime except for the periodic defrosting of the trains. Operating costs have been considerably below conventional absorption gasoline-plant costs. And the investment cost is a little more than half the cost of an equivalent absorption plant. The plant was designed and built by Stone & Webster Engineering Company. ★ ★ ★

P 263.

The Knocking Behavior of Fuels and Engines

"Severity Patterns" for engines must be established before a commercial fuel's knock rating can be predicted

R. V. Kerley and K. W. Thurston
Ethyl Corporation

REFINERS normally control the antiknock quality of automotive gasoline by using either the Research or Motor method or both to evaluate these fuels in knock-test engines. The apparent lack of correlation, however, between the knock-test ratings obtained by these laboratory methods and those secured in passenger-car engines has been a continuous problem.

As one means of achieving a better understanding of the mutual relationship of engines and fuels, Ethyl Corporation Research Laboratories have recently developed a nomographic method for correlating the laboratory ratings and road preformance of fuels. This method uses both the Research and Motor octane numbers of fuels to establish "engine-severity" patterns.

A test fuel is said to be "sensitive" if its octane number varies over a wide range when the fuel is rated in various engines. This sensitivity is determined in terms of the behavior of the test fuel relative to primary reference fuels. An engine that gives a low rating to a sensitive fuel is generally called a "severe" engine. On the other hand, an engine that gives a high rating to a sensitive fuel is said to be a "mild" engine. In contrast to the term "sensitive," which is applied to fuels and is relative to a specific primary reference fuel system, the term "severe," which is applied to engines, has not been generally defined relative to specific reference engines.

Starting with the realization that both Research and Motor ratings are important to the behavior of a fuel in a passenger car engine, a graph was constructed that would permit both to be shown. This is illustrated in Fig. 1. The Research octane numbers of a series of sensitive fuels were obtained and plotted on the vertical line marked "Research." Similarly, the octane numbers of these fuels were determined by the more severe Motor method and plotted on the line marked "Motor." Connecting the Research rating and Motor rating for each "S" fuel by a straight line results in a series of "fuel sensitivity" lines sloping upward to the left. Since the Research and Motor methods differ only with respect to specified operating conditions, these lines emphasize that various ratings can be obtained on each fuel depending on the engine conditions used to make the fuel knock.

If these sensitive fuels are rated in a passenger car engine by the Modified Borderline method, it is possible to relate these ratings to the ratings obtained in a laboratory engine by the Research and Motor methods. Such a relation is also shown in Fig. 1, in which a line connects the ratings obtained for each of the fuels in a passenger car engine at 1000 rpm.

It will be noted that when the spark is set for borderline knock (in this case, zero spark advance), the relatively insensitive fuel S-3 rates higher (83 octane number) than its Research rating (80 octane number). As the spark is advanced at constant engine speed, each of the sensitive fuels is, in turn, brought into borderline knock. At the spark advance of 12 deg required to cause the more sensitive fuel S-9 to knock, this fuel would rate sligthly lower than its Research rating.

Fig. 2 shows the severity pattern for this engine at normal operating speeds and illustrates the very marked effect of engine speed on depressing the ratings of sensitive fuels. It is apparent that the spark advance used at each

Condensation of a paper presented at the SAE Fuels and Lubricants Meeting, Philadelphia, Pennsylvania, November 10, 1955.

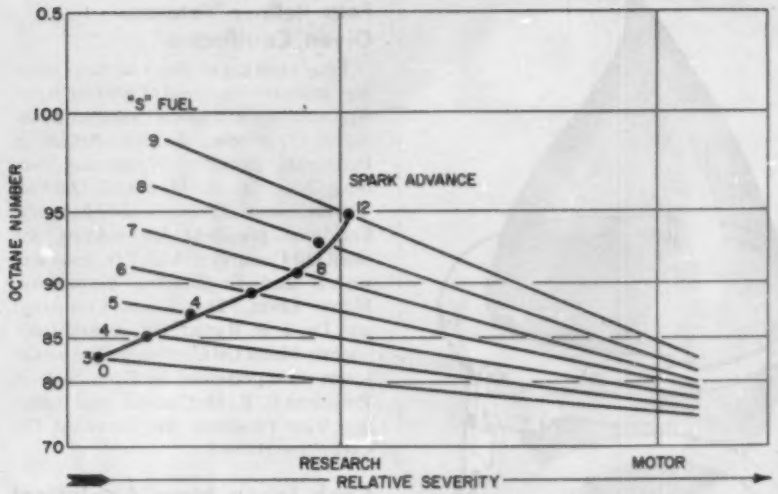


FIG. 1. Engine of make "D" severity line established by ratings of sensitive reference fuels at 1000 rpm.

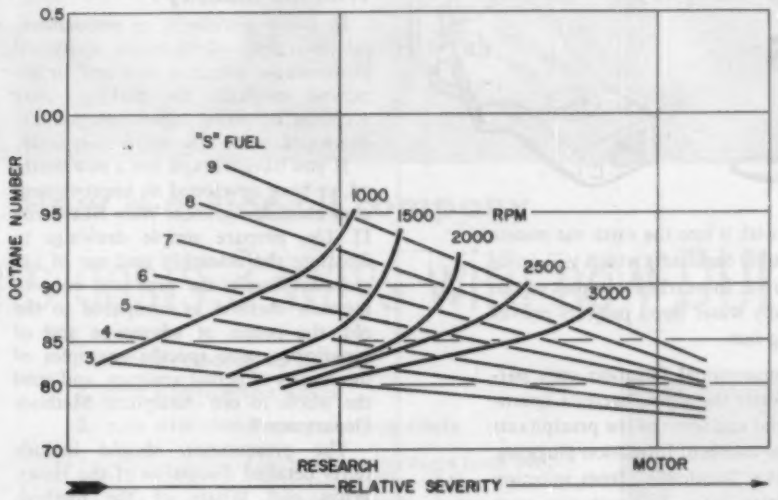


FIG. 2. Engine of make "D" severity pattern established by ratings of sensitive reference fuels at normal operating speeds.

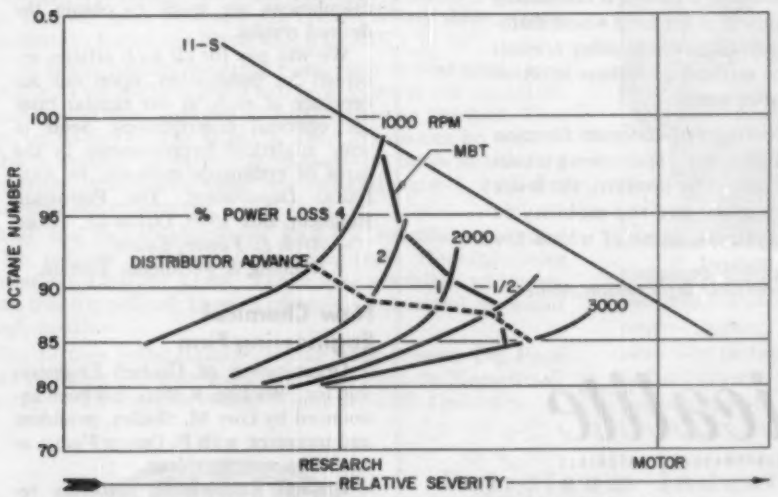


FIG. 3. Reduction in fuel requirement for engine make "D" resulting from choice of distributor advance below that which results in best torque.

speed actually determines the octane-number requirement of the engine at that speed. Therefore, the distributor spark advance curve chosen by the engine builder assumes an important role.

When establishing a distributor curve, the engine manufacturer normally reduces the spark advance to a value below that for best power in order to avoid knock on commercial fuels. The greatest compromise is usually made in the lower speed range where power losses of up to five per cent were observed at 1000 rpm for the three passenger car engines studied. The power losses caused by retarding the spark at full throttle in the low-speed range reduced the octane-number requirement of these engines by 3 to 9. Research octane numbers for fuels of normal commercial sensitivity. In general, engine output at higher speeds was not significantly affected by tailoring the distributor curve to fit fuels of normal sensitivity in the octane number range for which the engines were developed. These effects are shown in Fig. 3, which compares the engine severity with the standard distributor advance to the severity with minimum spark advance for best torque (MBT).

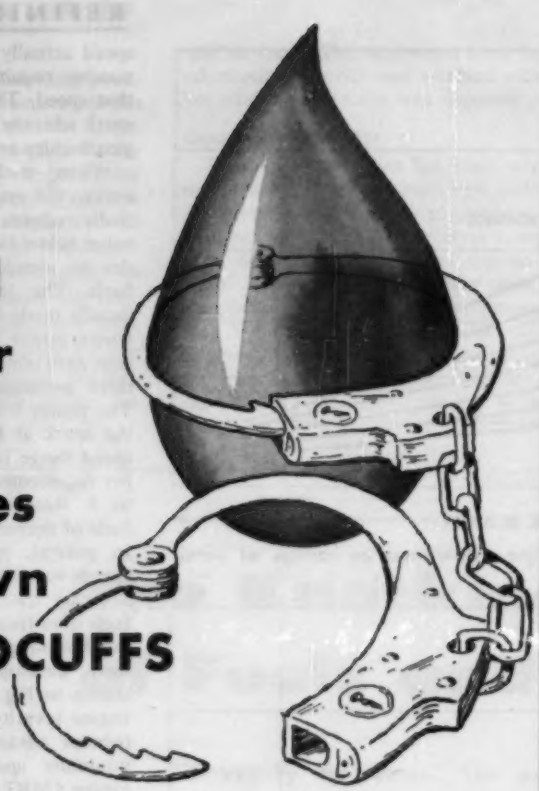
A study of the effect of manufacturing tolerances for distributors and the manner in which the basic distributor timing is set indicated that both factors markedly affect knocking characteristics of a given engine. The normal manufacturing tolerance for spark advance of + or — 2 crankshaft degrees from the standard distributor curve may change the fuel requirement by as much as 6 octane numbers in terms of either the Research or Motor methods.

This nomographic method also can be applied to other studies of the effects of engine design or operating conditions on engine severity. For example, this technique permits evaluation of the effects of changes in compression ratio, cylinder charge density, or intake-air and engine-coolant temperature.

Once the severity pattern for a given engine has been established, as shown in Fig. 2, the ratings of a commercial fuel in the engine can be predicted if the Research and Motor octane numbers of the fuel are known. Because of differences in engine design and operation, it is unlikely that severity patterns for one make of engine will determine both the octane-number level and the required fuel sensitivity for a commercial gasoline. However, severity patterns for several critical vehicle makes will permit reasonably accurate predictions of the Research and Motor octane numbers required on the road.

* * *

Flood water often carries its own HANDCUFFS



• All too often, flood water takes with it into the earth the means of its own strangulation—the invisible handcuffs which will gradually but surely slow or halt the drive. In nearly every part of the oil country, the experience of many water flood projects proves that this is not theory but crippling fact.

• Settling, sedimentation and conventional filtration only partially remove from the injection water the algae, bacteria (particularly the sulfate-reducing bacteria) and some of the precipitants which have been identified as major causes of formation plugging. But diatomite filtration unlocks the "handcuffs" from injection water, because its "sharp" filtration traps and removes even bacteria and other colloidal solids. The trouble-free experience of many flood projects now using diatomite filtration is convincing evidence of its effectiveness, particularly in the cases where diatomite-filtration flood projects are operating close to other projects which use conventional clarification methods and whose injection pressures continue to rise, month after month.

• Other advantages of diatomite filtration are the smaller space requirements (about 1/5 that of sand filter systems), the lower installation costs, and the mobility of diatomite systems, some of which are completely unitized.

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Four Refiner Veterans Given Certificates

Four veterans of the American refining industry received Certificates of Appreciation at a special banquet meeting of the refining division, American Petroleum Institute, Wednesday evening, May 16, in Montreal, Quebec. The men are C. E. Davis, until January, first vice president for refining for Shell Oil Company; A. J. Ely, Esso Research and Engineering Company; Harry Levin, The Texas Company; and Dr. J. B. Rather, Sr., retired from Socony Mobil Oil Company. The certificates were presented by Division Vice President E. B. McConnell, also Refining Vice President for Standard Oil Company (Ohio).

Cash In on New Analytical Methods! Share Your Methods With the Industry

In every petroleum or petrochemical laboratory where major analytical problems are attacked, new and/or improved methods for making more accurate or more rapid analyses are developed and employed in daily work.

If you have worked out a new method, or have developed an improvement over existing routines, Why Not Write IT Up, prepare simple drawings to illustrate the assembly and use of apparatus, discuss the pros and cons of the new method as compared to the old, the points of advantage and of superiority; give specific examples of the results of actual analyses, and send the whole to our Analytical Methods Department?

The presentation should include fairly detailed discussion of the Hows, Whys and Whats of the method, should discuss the chemistry involved and should show in exact detail how calculations are made to obtain the desired results.

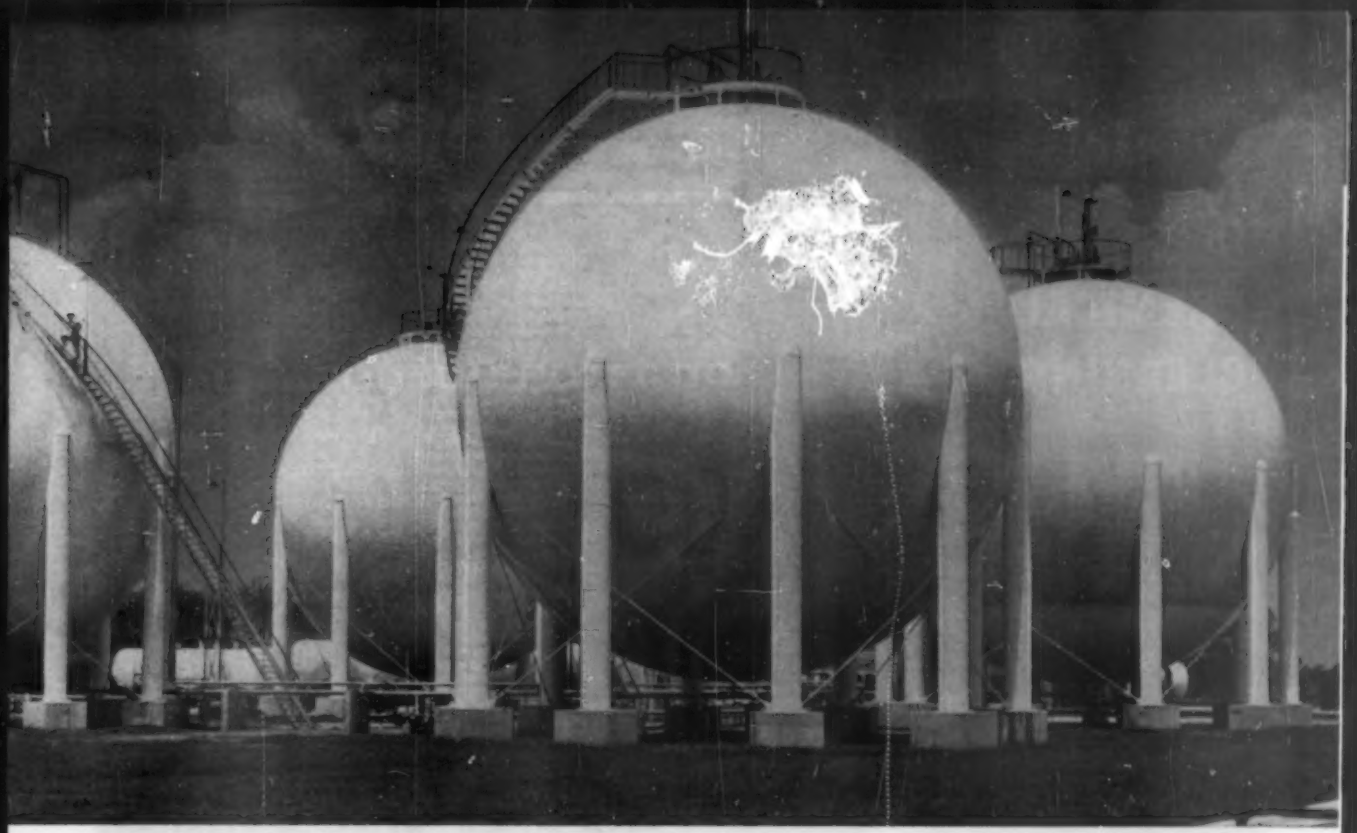
We will pay for all such articles accepted for publication, upon our acceptance of each, at our regular rates for editorial contributions. Send in your analytical improvements in the form of systematic methods, to Analytical Department, The Petroleum Engineer, Box 1589, Dallas 21, Texas.

—Arch L. Foster, Editor,
Refining & Petroleum Edition.

New Chemical Engineering Firm

Organization of Dushell Engineering, Inc., Wichita, Kansas, has been announced by Guy M. Shelley, president and treasurer, with F. Duane Fuqua as executive vice president.

Dushell Engineering performs refinery and chemical plant engineering, plant surveys, and economic studies.



How a major oil company

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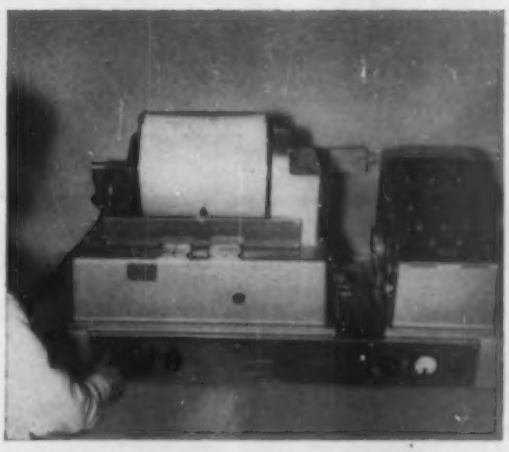
3. cuts maintenance painting costs

Leading petroleum engineers agree that painting a tank white cuts evaporation losses to a minimum. The white pigment combination used in formulating DULUX Tank White provides controlled chalking to give maximum reflectance... maximum durability. Because DULUX reflects the sun's rays so well, tank interiors are cooler. Many users report evaporation losses cut by as much as 80%.

You begin cutting painting costs even as you apply new DULUX. Two coats of paint can be applied in one operation —the second coat sprayed at right angles to the first. This way, up to five mils of DULUX Tank White can be applied without sagging or wrinkling. Because of these fast-drying properties, scaffolding costs are reduced—insect, and dirt collection are minimized.

And the new higher-build DULUX lengthens painting cycles, reduces maintenance-painting costs. Repaint cycles can be extended by years. Tanks *stay* sparkling white because this rugged paint resists corrosion, industrial gases and rough weather.

For further information, consult your nearest Du Pont Sales representative or write: E. I. du Pont de Nemours & Co. (Inc.), Finishes Division, Wilmington 98, Delaware.



FINGERPRINTING A FINISH. Here a Du Pont chemist uses infrared transmission spectrometer to identify and control chemical characteristics of resins, oils and finishes. The pattern it gives is like a fingerprint and may be used to trace extent of reaction that occurs in the manufacture of a resin.

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Du Pont's Motor Fuel Survey, April, 1956

City	PREMIUM Octane number Motor	PREMIUM Octane number Research	PREMIUM TEL Content cc/gal	REGULAR Octane number Motor	REGULAR Octane number Research	REGULAR TEL Content cc/gal
Aberdeen, S. D.	86.1	94.0	2.38	82.1	86.1	2.17
Amarillo, Tex.	86.6	96.2	2.35	82.7	87.6	2.48
Atlanta, Ga.	86.6	96.8	2.28	83.5	89.7	2.44
Bakersfield, Calif.	87.9	95.1	2.93	79.8	85.8	2.48
Baltimore, Md.	87.2	97.0	2.54	84.5	91.7	2.55
Boston, Mass.	86.3	96.6	2.26	84.8	92.2	2.35
Calgary, Alberta	82.7	90.7	2.67	79.8	84.0	2.37
Casper, Wyo.	83.0	92.5	1.44	79.8	85.2	1.87
Charlotte, N. C.	86.2	96.8	2.38	83.0	89.8	2.45
Chicago, Ill.	87.0	95.2	2.50	83.3	88.9	2.19
Cincinnati, Ohio	86.0	95.7	1.85	84.1	90.5	2.20
Cleveland, Ohio	86.5	95.7	2.09	84.0	91.3	2.10
Columbus, Ohio	85.9	96.0	2.02	83.6	90.7	2.00
Corpus Christi, Tex.	87.8	97.2	2.84	84.7	88.4	2.66
Dallas—Fort Worth, Tex.	87.0	97.2	2.63	82.7	88.0	2.62
Davenport, Iowa	85.0	94.2	2.24	81.7	87.0	2.15
Denver, Colo.	83.8	92.5	1.77	80.5	85.8	1.64
Des Moines, Iowa	85.1	94.1	2.20	82.1	86.4	2.17
Detroit, Mich.	86.6	95.9	2.33	83.7	90.7	1.96
Edmonton, Alberta	83.3	91.2	1.78	79.0	84.3	1.56
El Paso, Tex.	86.4	95.6	2.51	81.4	86.0	2.28
Great Falls—Billings, Mont.	83.7	94.4	1.84	79.0	86.4	1.68
Houston, Tex.	87.2	97.5	2.81	83.8	89.0	2.70
Indianapolis, Ind.	85.9	96.0	2.21	82.9	89.6	1.87
Jacksonville, Fla.	86.5	96.7	2.39	83.9	91.1	2.48
Kansas City, Mo.	85.2	94.4	2.60	81.9	86.8	2.33
Little Rock, Ark.	85.9	97.5	2.78	83.5	89.0	2.39
Los Angeles, Calif.	85.0	96.0	2.55	79.2	86.1	1.36
Louisville, Ky.	86.4	96.4	2.45	83.4	89.5	2.32
Memphis, Tenn.	87.2	97.0	2.62	83.9	89.5	2.41
Milwaukee, Wis.	86.4	95.1	2.26	82.7	89.0	2.11
Minneapolis, Minn.	85.2	94.7	2.03	81.9	86.5	1.82
Montreal, Quebec	85.1	95.1	2.19	83.8	89.5	1.87
Nashville, Tenn.	86.8	97.4	2.64	83.7	89.2	2.48
New Orleans, La.	86.7	96.7	2.66	83.6	88.8	2.59
New York, N. Y.	86.8	96.7	2.67	84.9	92.0	2.57
Omaha, Neb.	85.4	94.3	2.26	81.7	85.9	2.06
Philadelphia, Pa.	86.7	96.4	2.27	84.5	91.6	2.37
Pittsburgh, Pa.	86.2	96.5	2.35	84.9	91.9	2.53
St. Louis, Mo.	86.0	94.6	2.39	82.1	86.8	2.24
Salt Lake City, Utah	83.7	92.3	1.52	78.9	82.2	1.79
San Francisco, Calif.	86.4	96.6	2.57	80.8	86.4	1.40
Seattle, Wash.	85.3	95.8	1.96	80.7	86.6	0.98
Shreveport, La.	87.4	97.1	2.82	83.6	88.8	2.60
Spokane, Wash.	84.9	95.8	1.92	80.6	86.4	1.44
Toronto, Ont.	85.8	95.1	2.25	82.5	89.2	1.51
Tulsa-Oklahoma City, Okla.	86.4	94.6	2.49	82.6	86.6	2.11
Vancouver, B. C.	84.3	94.5	1.23	80.5	85.5	0.80
Wichita, Kans.	85.6	94.2	2.21	82.2	86.6	1.94
Winnipeg, Man.	84.0	93.8	1.73	81.4	87.2	1.16

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(A) Round valve surface is streamlined. No obstructions to restrict the flow. (B) Ball-guided valve rotates and swings with each stroke of the pump. Each turn, each swing . . . a lapping action, a continuing perfect seat. (C) Free vertical action assures instant opening and closing. Ball stem is a frictionless guide.

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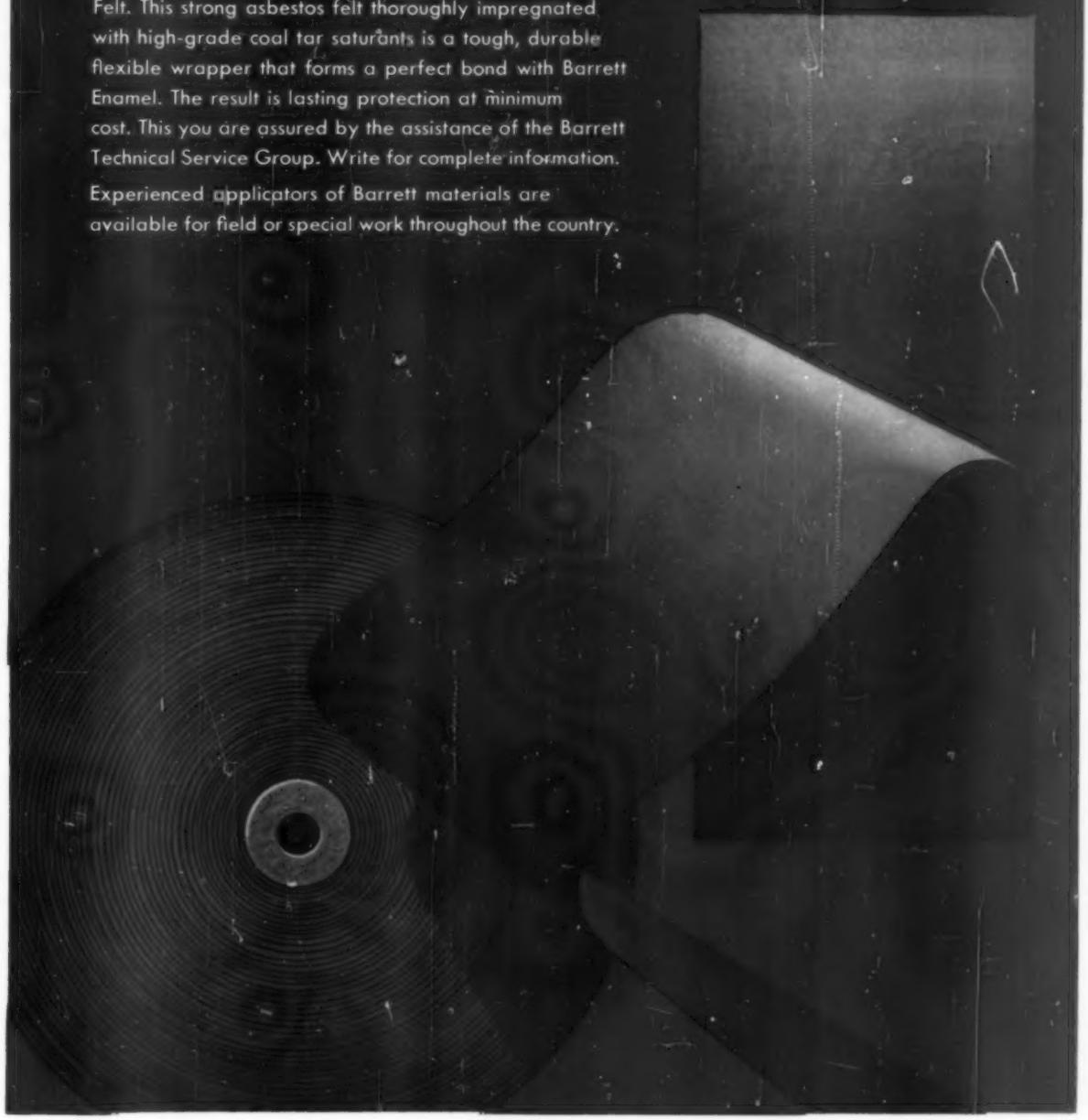

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Low-Cost Installation

Control is factory-assembled and bussed —conduit layout simplified. Lineup requires only one incoming feeder.

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PIPE LINE DEVELOPMENTS ★ ★ ★

Roundup of Current Planned and Proposed Construction

The following tables list the company, mileage, pipe size, and location of proposed pipe line projects — crude, products, and natural gas — reported to The Petroleum Engineer. Company addresses are given where furnished or known.

CRUDE LINES

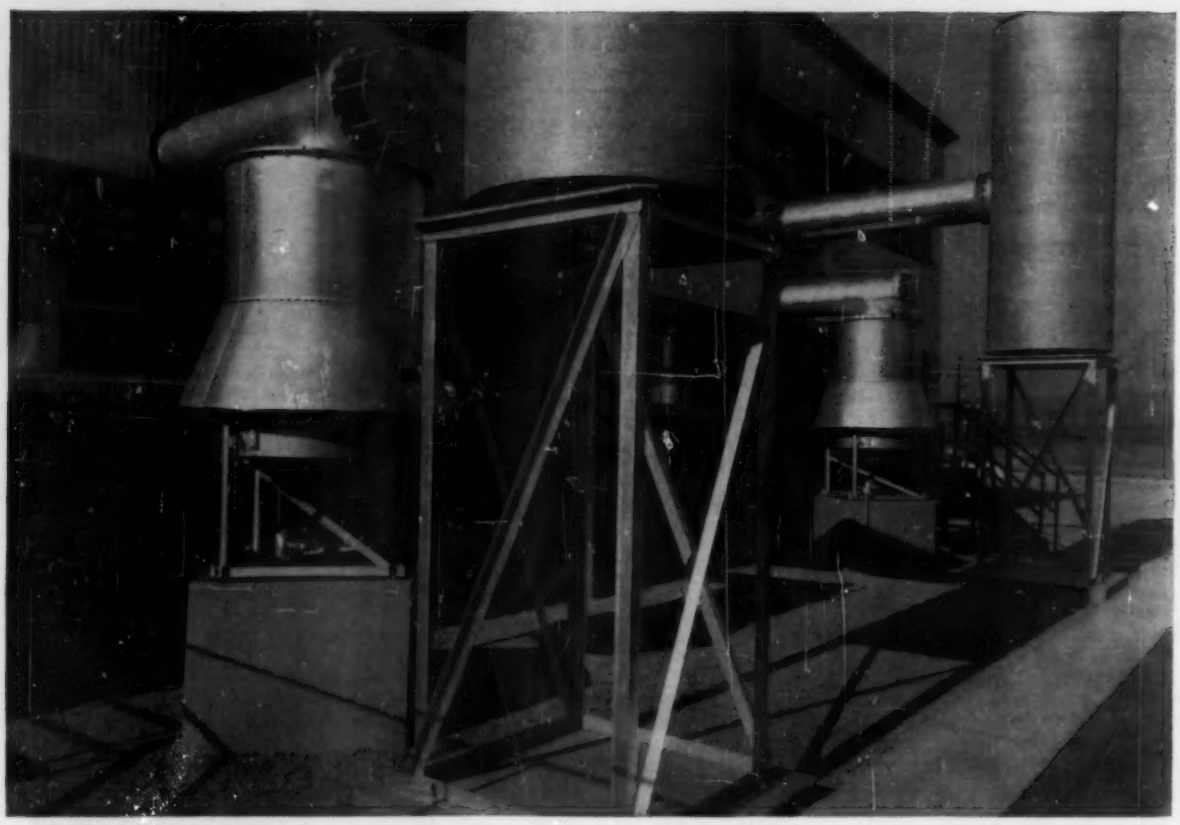
Name of Company	Miles	Size	Location
Ar-Mex Pipe Line Company, Dallas, Texas	790	12-14	Guernsey, Wyoming to Coolidge, Arizona
Kaybee Pipe Line Company, Muskegon, Michigan	46	10	Griffith, Indiana to New Buffalo, Michigan
National Co-Operative Refinery Association, Kansas City, Missouri	30	8	Lyons to McPherson, Kansas
Offshore Gathering Company, Houston, Texas	364	20	Offshore line in Gulf of Mexico from Sabine Pass to Mississippi River
Pasotex Pipe Line Company, Houston, Texas	76	20	Wink to El Paso, Texas, to replace smaller system
Powder River Pipe Line Company, Casper, Wyoming	436	10-16	Williston Basin to Laurel-Billings, Montana, refining area
Sinclair Pipe Line Company, Independence, Kansas	150	20	Mexia to Houston, Texas. Replacement of existing line
	12	6	North Madill field to Cumberland field terminal, Oklahoma
Socony Mobil Oil Company de Venezuela and Sinclair Oil and Refining Company	211	20	From Silvester field, near Barinas, to Puerto Cabello, Venezuela
South Saskatchewan Pipe Line Company	58	12	Gathering main from Dollard field to Cantuar, Saskatchewan.
Stanmount Pipe Line Company	140	10	Beaver Lake field, North Dakota to Cromer, Manitoba station on Interprovincial Pipe Line
Tecumseh Pipe Line Company	—	20	New line between East Chicago, Indiana, to Cygnet, Ohio
Trans-Border Pipe Line Company	110	—	Skagway, Alaska to Whitehorse, Yukon, Territory
Trans-Prairie Pipe Lines, Ltd., Winnipeg, Manitoba	17	3-6	Lines in Cromer and Virden areas, Manitoba
Union Oil Company, Los Angeles, California	815	—	Considering line from shale oil plant at Rifle, Colorado, to Los Angeles area
U. S. Department of Defense	97	—	Crude line from Elk Hills Naval Reserve to Los Angeles

PRODUCTS LINES

Name of Company	Miles	Size	Location
Ar-Mex Pipe Line Company, Dallas, Texas	60	8	Coolidge to Phoenix, Arizona
	70	8	Coolidge to Tuscon, Arizona
California-Oregon Pipe Line System, Crescent City, California	103	6	Crescent City, California to Medford, Oregon
Deep Rock Gas Company (LPG Line)	120	6	Tioga, North Dakota to U. S.-Canadian Border
El Paso Natural Gas Company, El Paso, Texas (LPG Line)	60	10	Farmington to Gallup, New Mexico
International Pipe Line, Inc., Minneapolis, Minnesota	132	8	Wrenshall to Minneapolis, Minnesota
Maico Pipe Line, Inc., Roswell, New Mexico	91	6	Prewitt to Albuquerque, New Mexico
	138	6	Artesia to Newman, New Mexico
Phillips Pipe Line Company, Bartlesville, Oklahoma	50	12	Sweeny to Pasadena, Texas, refinery near Houston
Sioux Oil Company	50	6	Newcastle, Wyoming to Rapid City, South Dakota
Texas Eastern Transmission Corporation, Shreveport, Louisiana	1168	16-20	Plans to convert the "Little Inch" line between Beaumont, Texas and Moundsville, West Virginia upon completion of new gas facilities. Has FPC aproval to abandon gas service from the "Little Inch"
Winnipeg & Central Gas Company, Winnipeg, Manitoba (LPG Line)	210	6	U. S.-Canadian border to Winnipeg (See also Deep Rock Gas Company listing)

GAS LINES

Name of Company	Miles	Size	Location
Alberta Gas Trunkline, Calgary, Alberta	315	6-34	Gas gathering system in Alberta fields to serve proposed Trans Canada Pipe Lines
American Louisiana Pipe Line Company, Detroit, Michigan	117	22	Defiance, Ohio to Bridgman, Michigan
Arkansas-Louisiana Gas Company, Shreveport, Louisiana	76	24	Loops in Louisiana
Atlantic Seaboard Corporation, Charleston, Virginia	31	—	Parallel existing line in West Virginia and Virginia
	55	—	Interconnecting lines between Lost River station, Hardy County, West Virginia and Bickers station in Greene Virginia
Carolina Natural Gas Corporation	185	2-12	Lines in North and South Carolinas



AAF Cycoils Type "P" protect Cooper-Bessemer engines from costly dust trouble at Sugar Grove, Ohio pumping station of Ohio Fuel Gas Company.

CYCOILS tell a *Sweet Story* at Sugar Grove

Ohio Fuel Gas Company is mighty particular about its machinery and equipment. They have to be. The big Cooper-Bessemer engines in this pumping station at Sugar Grove, Ohio, for instance, are the heart of the area's fuel gas supply. Dirty air could cause real damage.

What better reason for those AAF Cycoils Type "P" . . . protecting vital equipment, assuring uninterrupted flow of gas! Type "P" Cycoil utilizes a new principle in oil bath air filters—a perforated entrainment plate, placed in the air stream. Oil flows over the plate from a central distributing head. Metered orifices in the plate are calibrated to increase velocity of air flow through the openings to entrain the oil that tends to spill over the edges, and distribute air flow uniformly over the area. Entrainment accomplished, air then passes upward through primary and secondary filters for removal of dust and oil content. Result is air that's virtually 100% *dust-free!*

Here's the kind of protection your engines and compressors need. Protection that saves money, blocks trouble. You get it only with AAF Cycoil Type "P". So get the facts. Write for Bulletin 160.

Type CMS Multi-Duty Filters

Type G Pipeline Air Filters

AAF

American Air Filter

COMPANY, INC.

304 Central Avenue, Louisville 8, Kentucky

American Air Filter of Canada, Ltd., Montreal, P. Q.

BETTER AIR IS OUR BUSINESS

Type OCH Intake Air Filters

Cycoil Oil Bath Air Filters

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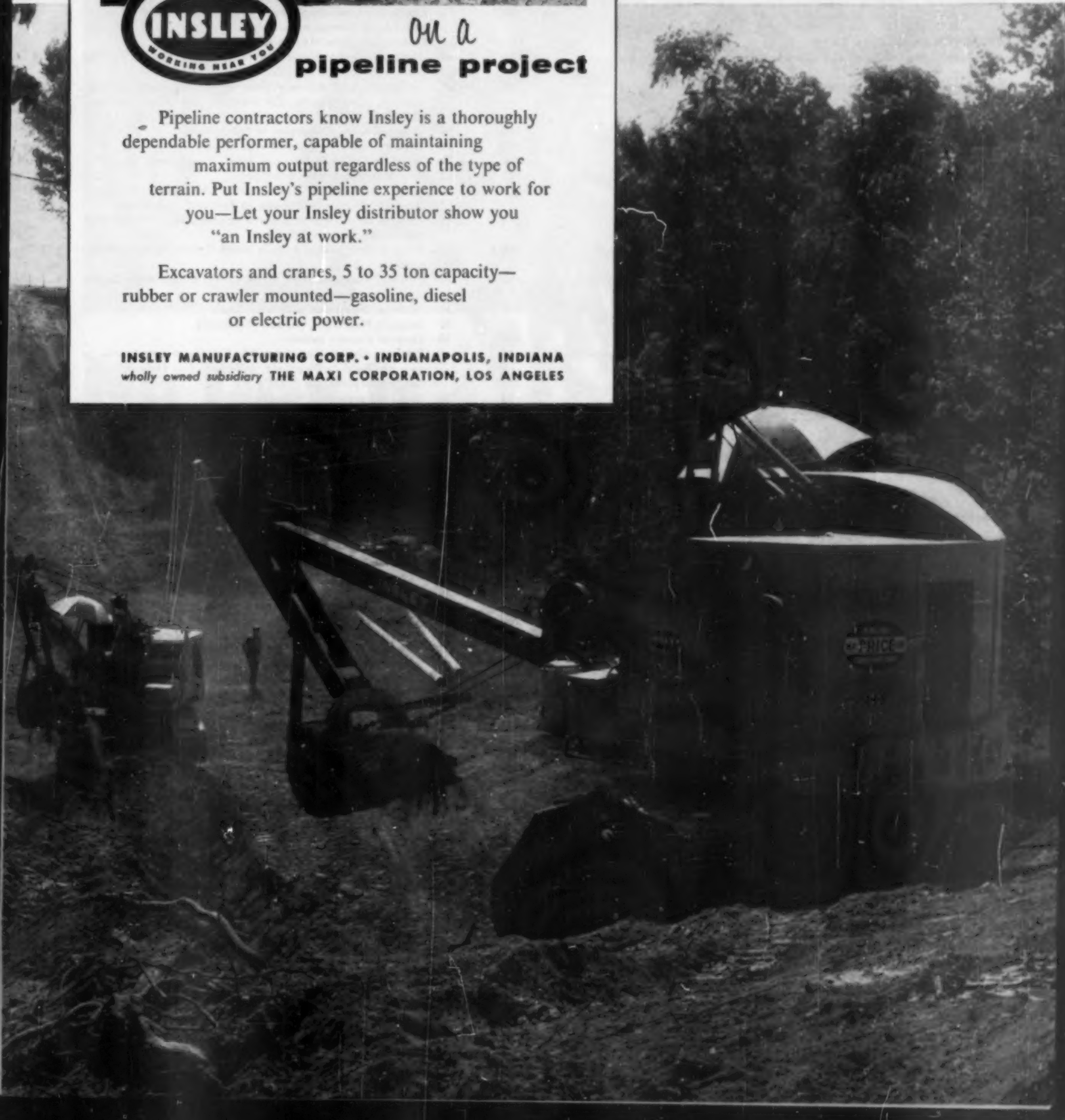
THERE'S AN INSLEY WORKING NEAR YOU

on a
pipeline project

Pipeline contractors know Insley is a thoroughly dependable performer, capable of maintaining maximum output regardless of the type of terrain. Put Insley's pipeline experience to work for you—Let your Insley distributor show you "an Insley at work."

Excavators and cranes, 5 to 35 ton capacity—rubber or crawler mounted—gasoline, diesel or electric power.

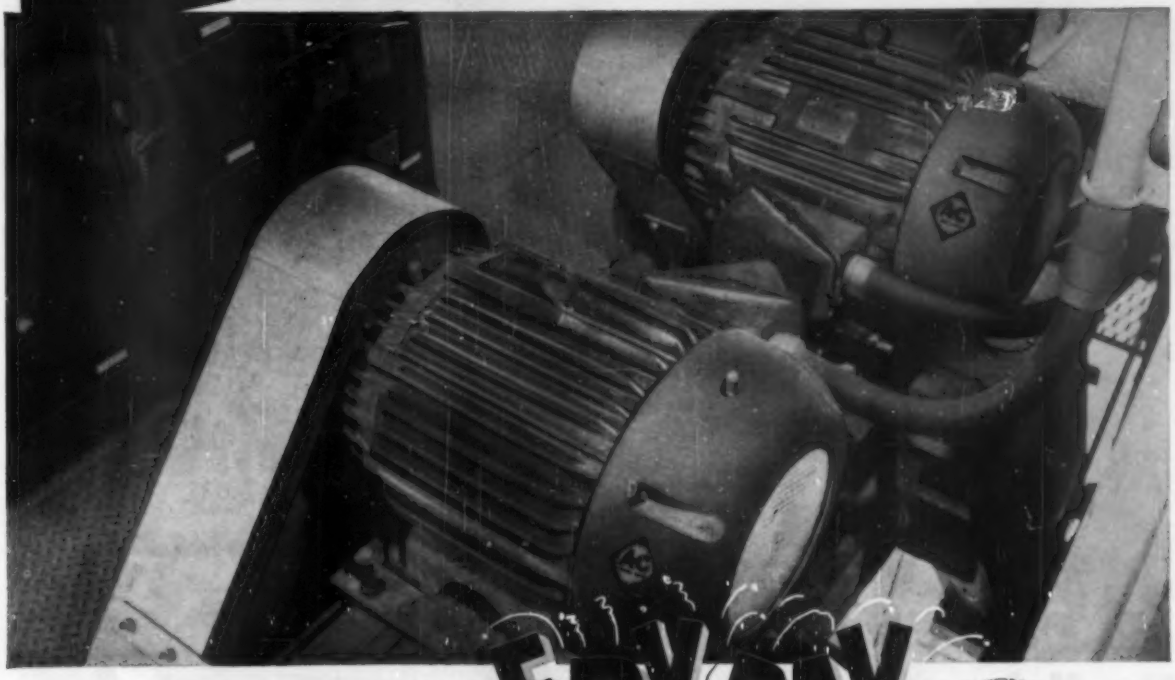
INSLEY MANUFACTURING CORP. • INDIANAPOLIS, INDIANA
wholly owned subsidiary **THE MAXI CORPORATION, LOS ANGELES**



GAS LINES (Continued)

Name of Company	Miles	Size	Location
Andes Pipeline Corporation	500	12	Villamontes, Bolivia, to Yuni, Bolivia, through the Andes Pass, to Antofagasta, Chile.
Central Hudson Gas & Electric Corporation, Albany, New York	48	12	Albany to Kingston, New York
Central Kentucky Natural Gas Company, Charleston, West Virginia	21.1	20-24	New lines in Kentucky
Cities Service Oil Company, Bartlesville, Oklahoma	70	—	Gas gathering system on the Roberts Ranch, Midland County, Texas
Coastal Transmission Corporation, Dallas, Texas	562	22-26	McAllen, Texas to Baton Rouge, Louisiana
	272	Var.	Gathering lines in Rio Grande Valley, Texas
Colorado Interstate Gas Company, Colorado Springs, Colorado	110	6-8	Julesburg area to Denver, Colorado
	307	30	Main line between Idalia, Colorado and Beatrice, Nebraska.
	160	26	Lateral between Carr, Colorado and Idalia.
	75	26	Lateral between Kit Carson, Colorado and Idalia.
	215	20-26	Parallel existing line between Texas and Oklahoma Panhandle gas fields and Kit Carson, Colorado.
	34	16	Gathering lines from Keyes field, Oklahoma and Greenwood field, Kansas to new line.
El Paso Natural Gas Company, El Paso, Texas	547	34	Farmington, New Mexico to Topock, Arizona
Houston Texas Gas & Oil Company, Houston, Texas	961	12-20	Baton Rouge, Louisiana to Miami, Florida, serving Florida area with various laterals
Iroquois Gas Corporation, Buffalo, New York	36	Var.	Gathering and delivery lines in underground storage area in Chautauqua, Cattaraugus and Erie Counties, New York
Lone Star Gas Company, Dallas, Texas	230	30	Cotton County, Oklahoma to Fritch, Texas
	205	24	Snyder, Texas to Cotton-Fritch line
Michigan-Wisconsin Pipe Line, Detroit, Michigan	724	4-24	Loops on system in Missouri, Iowa, Illinois, and Wisconsin
Michigan-Consolidated Gas Company, Detroit, Michigan	25	12	Sparta to Muskegon, Michigan
Midwestern Gas Transmission Company, Houston, Texas	1112	12-24	Main line from U. S.-Canadian Border near Emerson, Manitoba-Noyes, Minnesota to Portland, Tennessee
	648	3-18	Laterals off main line to serve communities in Minnesota, North Dakota, and Wisconsin
Montana-Dakota Utilities Company, Minneapolis, Minnesota	41.8	12	Tioga-Beaver Lodge field in North Dakota to main transmission line
Natural Gas Pipeline Company of America, Chicago, Illinois	350	20-26	Fritch, Texas to Wise County, Texas, through Southwest Oklahoma
	398	36	Beatrice, Nebraska to Joliet, Illinois.
	91	30	Loops in Nebraska, Kansas, Oklahoma.
Nevada Natural Gas Company, Las Vegas, Nevada	114	10	Loop of present system
New York State Natural Gas Corporation, Pittsburgh, Pennsylvania	27	—	Extend existing line from Elk County, Pennsylvania to new gas field in Clearfield, Jefferson, and Indiana Counties, Pennsylvania.
Northern Natural Gas Company, Omaha, Nebraska	15	24	Loops on system in Nebraska
	28	24	Ogden to Redfield storage area, Iowa
	168	20	St. Paul-Minneapolis to Duluth, Minnesota and Superior, Wisconsin
	163	10-12	Main lines in South Dakota
	307	Var.	Branch lines in South Dakota, Minnesota, Iowa, and Wisconsin
	100	20-24	Savanna Creek field, Alberta to Alberta-Montana border near Cardston, Alberta.
Northern Plains Natural Gas Co. (Subsidiary Northern Natural Gas Co.)	1100	26	Alberta-Montana border to Minneapolis, Minn.
Northwest Utilities, Ltd.	42	—	Bonnie Glen to Edmonton, Alberta
Offshore Gathering Company, Houston, Texas	364	30	Offshore gas line in Gulf of Mexico from Sabine Pass to Mississippi River
Pacific Gas & Electric, San Francisco, California	150	34	Loops on Topock, Arizona to Milpitas, California system
Permian Basin Pipeline Company, Omaha, Nebraska	19	16	Gathering system for 15 West Texas gas fields
Pioneer Natural Gas Company, Amarillo, Texas	261	3-22	New lines, loops, replacements and irrigation feeder lines in the Panhandle and South Plains of Texas
Shenandoah Gas Company, Winchester, Virginia	39	3-8	Middleton, Virginia to Martinsburg, West Virginia
Southern Counties-Southern California Gas Companies, Los Angeles, California	236	30	Topock, Arizona to Newhall, California
Southern Natural Gas Company, Birmingham, Alabama	52	—	Loops on system in Alabama, Georgia, Louisiana, and Mississippi
Tennessee Gas Transmission Company, Houston, Texas	221	26-30	Loops in Ohio and Kentucky
	100	—	New gathering lines in Texas and Louisiana
	162	—	Loops in Kentucky, Ohio, and Pennsylvania
Texas Eastern Transmission Corporation, Shreveport, Louisiana	422	30	McAllen to Vidor, Texas
	530	30	Loops on system from Texas to New Jersey
	180	Var.	Supply, lateral, and gathering lines
Trans Canada Pipe Lines, Ltd., Calgary, Alberta	2247	14-24	Alberta area to Toronto, Montreal, and other eastern Canadian areas
Trans-Carolina Pipeline Corporation, Raleigh, North Carolina	840	Var.	New pipe line system to serve 40 communities in North and South Carolina.
Transcontinental Gas Pipe Line Corporation, Houston, Texas	12.3	—	Gathering lines in Live Oak field, Vermilion Parish, Louisiana
	160	36	Additional construction planned for 1956 in Alabama,
	68	30	Georgia, South Carolina, North Carolina, Mississippi, Virginia, Maryland and Pennsylvania
Union Gas Company of Canada, Chatham, Ontario	180	—	Dawn Storage Field to Hamilton, Ontario
United Natural Gas Company	50	12	Elk County to Jefferson County, Pennsylvania
Utah Natural Gas Company, Salt Lake City, Utah	40	16	Orem to Salt Lake City, Utah
Virginia Natural Gas Company	153	—	Buckingham to Richmond and Portsmouth, Virginia

There's **MORE** Cooling Surface in these deep-ribbed **MOTORS**



No Day is FRYDAY

with these Allis-Chalmers MOTORS

● Frying of insulation is impossible under normal conditions with the extra-large cooling surface of Allis-Chalmers rib-type TEFC motors. The result—you expect and get longer motor life.

The engineered partner of A-C motors is Allis-Chalmers control.

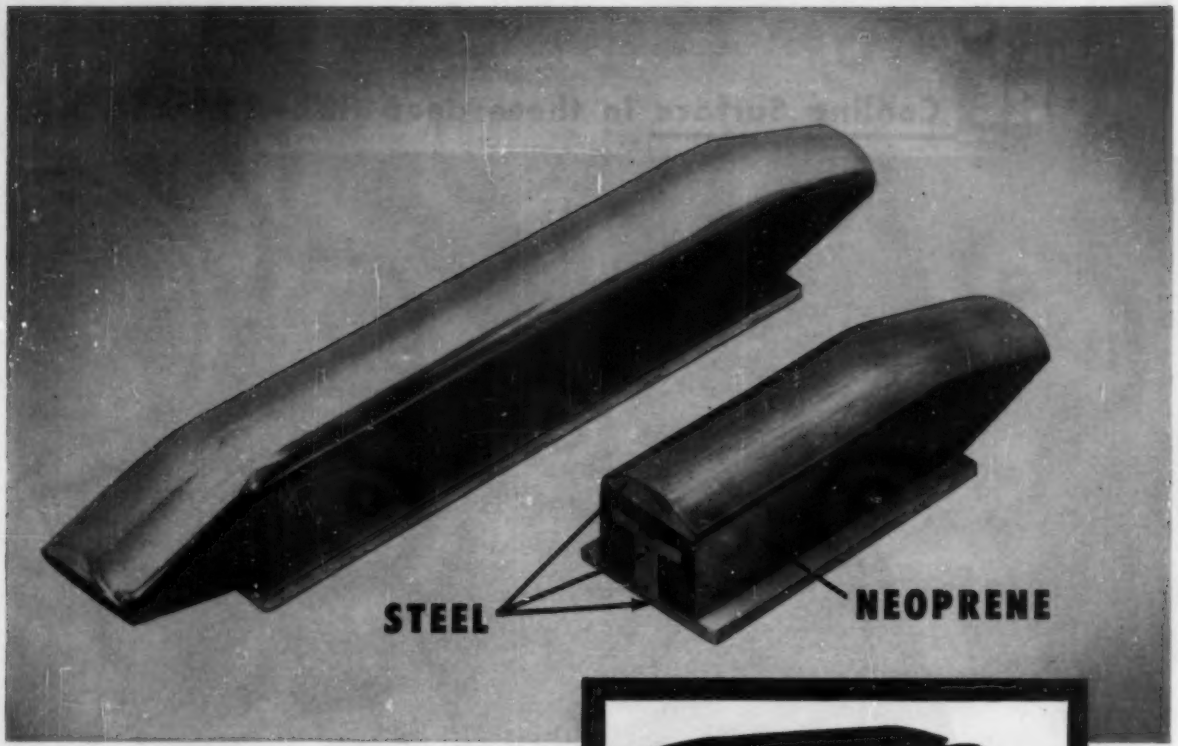
Get Complete Information

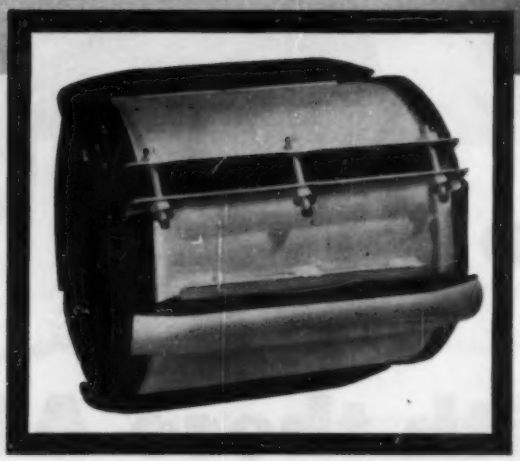
As a new machinery component or as replacement, specify Allis-Chalmers. Discuss your particular application with your nearby A-C distributor, A-C district office, or write Allis-Chalmers, General Products Division, Milwaukee 1, Wisconsin.

ALLIS-CHALMERS

A-C ALLIS-CHALMERS

A-4940





The Maloney Crossing Insulator With The Runners That Make Sense

The Maloney shoe is a new sled type. The rubbing surface is quarter round steel giving point contact with the casing which permits easy movement on installation. The long runners are tapered enough to let the carrier pipe slide over any casing welds that may be present. The tapered runners also facilitate easy entry of the carrier pipe into the casing.

Bonded metal-to-neoprene-to-metal on the runner insulates and also permits flexibility to compensate for pipe shifting and acts as a shock absorber to prevent damage due to sudden heavy loads.

"Something from the Irishman"

F. H. MALONEY *Company*

2301 TEXAS AVE. • FA 3-3161 • HOUSTON

LOS ANGELES TULSA

Since 1932
Precision In Rubber-Metal-Plastics

Like standard Foxboro Humitex Charts, these new *stabilized* charts have extra-high legibility too. Easy-to-read gray printing against the chart's smooth, white background brings out the full brilliance of Foxboro Recording Inks.

Here are the charts specifically designed to meet the high-accuracy requirements of "cash register" metering . . . Foxboro *stabilized* Humitex Charts. These advanced charts feature plastic-laminated paper — assure you *real* dimensional stability under the widest variations in temperature and humidity. In an extensive series of laboratory and field tests, Foxboro *stabilized* Humitex Charts were found to have only ¼ to ⅓ as much dimensional error as the highest grade of standard charts!

Foxboro *stabilized* Humitex Charts are your assurance of consistent, high-fidelity records — wherever you meter — wherever you compute. Try them at our expense. Write for samples and quotation. The Foxboro Company, 386 Norfolk St., Foxboro, Mass., U.S.A.

FACTORIES IN THE UNITED STATES, CANADA, AND ENGLAND

FOR MORE ACCURATE RECORDS **FOXBORO**

REG. U. S. PAT. OFF.

Bucyrus-Erie Dragshovels

SPEED UP TOUGH PIPELINE TRENCHING

Rough and rocky trenching like this calls for the kind of dependable performance you get from a Bucyrus-Erie dragshovel. This 22-B is working in northern Pennsylvania on a 24-in. natural gas line.

High-output is a traditional characteristic of Bucyrus-Erie dragshovels because of the high hoist speed and extra power on the digging stroke. The cambered boom lets you dig in close to crawlers. The dipper has sloping sides, side cutters with straight edges, and extended lip area for fast digging and heaped loads.

Tractor-type treads have deep grousers for sure traction in soft ground and for climbing steep grades. Added clearance lets you travel over rocks, stumps and other obstacles—16½ in. on the 15-B, and 20¾ in. on the 22-B. Special sealing protects track-roller bearings against damage from water, dust, dirt and grime.

More and more spreads are demonstrating that it pays to depend on Bucyrus-Erie dragshovels. Your distributor will give you complete details on the ½-yd. 15-B and ¾-yd. 22-B.

235E56

BUCYRUS ERIE

South Milwaukee Wisconsin

Typical installation of American Hammered Conformable Oil Rings

Insures constant unit pressure for positive oil control!

You keep your oil consumption down when you install Koppers American Hammered Conformable Oil Rings! This service-tested piston ring conforms readily to meet cylinder distortion because its flexible cast iron member is pressed outward by an abutment type spring which exerts uniform radial pressure around the entire circumference.

Narrow bearing surfaces on either side of the channel give the ring a uniform unit pressure on the cylinder, enabling it to seat promptly and assuring maximum removal of excess oil throughout its lifetime. And the Conformable Oil Ring has a longer useful life because its low spring rate and uniform lands result in negligible changes in pressure as the ring wears.

Easily installed, it is ideal for both 2-cycle and 4-cycle Diesel & Gas engines; comes in 4″ to 25″ diameters with a minimum width of ¼″. Write, wire or phone us today for full information on how the Conformable Oil Ring can improve *your* operation . . . or for expert help in *any* piston or sealing ring problem. KOPPERS COMPANY, INC., *Piston Ring Dept.*, 1706 Hamburg Street, Baltimore 3, Maryland.

KOPPERS

METAL PRODUCTS DIVISION • KOPPERS COMPANY, INC. • Baltimore, Maryland

This Koppers Division also supplies industry with Fast's Couplings, Aeromaster Fans, Koppers-Elex Electrostatic Precipitators and Gas Apparatus.

Engineered Products Sold with Service

AMERICAN HAMMERED
Industrial Piston Rings

KOPPERS COMPANY, INC., *Piston Ring Dept.*, 1706 Hamburg Street, Baltimore 3, Md.

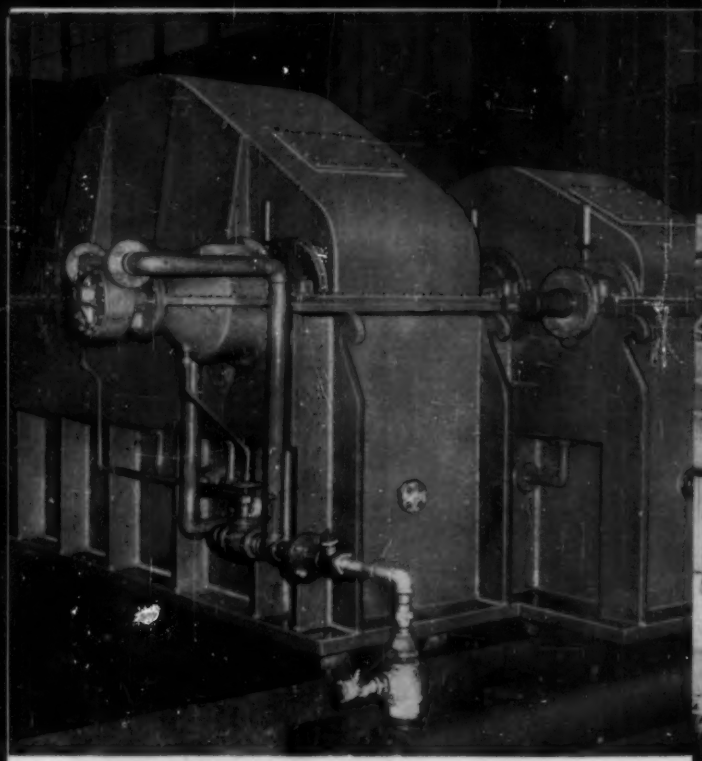
Gentlemen: Please send me full information on your Conformable Oil Ring.

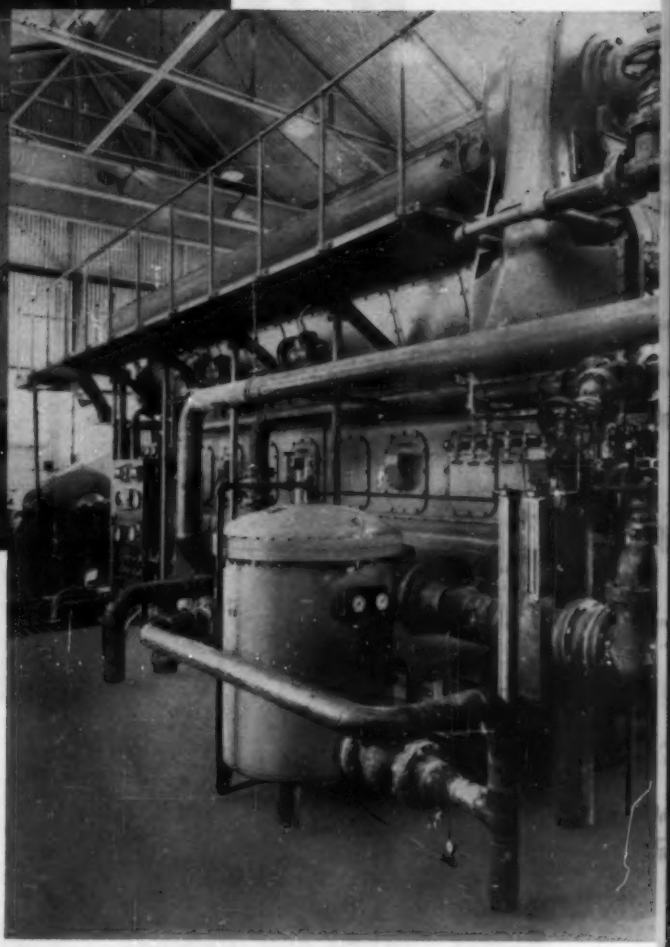
Name .....

Company .....

Address .....

City ..... Zone ..... State .....





"Satellite" pipeline station, remotely controlled, uses Western Gear two-stage high speed drive

REMOTE CONTROL operation from a point many miles away is a notable feature of the isolated Gulf-Interstate Gas Company's gas line pumping station near Stanton, Kentucky. Another modern feature is its two-stage high speed unit especially designed and manufactured by Western Gear, shown at upper left. This "custom-engineered" unit is driven by a Cooper-Bessemer 16-cylinder engine operating on natural gas from the pipeline. The engine speed of 360 RPM is stepped up by the high speed unit with a ratio of 16.8:1 driving the centrifugal compressor at 6,055 RPM. The entire pipeline station can be placed into operation and completely controlled by a telemetering system miles away.

Pipeline experts consider this station one of the most modern and advanced systems of its kind to date. Western Gear's long experience, dating back to 1888, made it the logical choice to design and build the high speed unit so essential to efficient performance of this significant installation. This experience is always available and Western Gear engineers are glad to help solve any problem involving mechanical power transmission equipment for the petroleum industry. Write General Offices, Western Gear Corporation, P. O. Box 182, Lynwood, California.

"The difference is reliability" • *Since 1888*

5804

PLANTS AT LYNWOOD, PASADENA, BELMONT, SAN FRANCISCO (CALIF.), SEATTLE AND HOUSTON
REPRESENTATIVES IN PRINCIPAL CITIES

WESTERN GEAR Corporation
ENGINEERS AND MANUFACTURERS

For hour after hour of sustained welding . . .

New G-E 200-amp Welder Delivers Steady Output Even at Full Load

Now, with the new G-E 200-amp engine-drive welder you can be sure of reliable construction welding—even for sustained operation. This powerful new welder makes it unnecessary to buy more expensive, higher rated machines just to make sure you get full 200-amp output when you need it.

This field-tested welder gives you steady output and 100% arc stability—hour after hour—even when operating at full load. This is made possible by combining a generator specially designed for field use with a direct-connected Hercules engine.

In addition, the high recovery voltage of the welder gives you complete freedom from "popouts," no matter what type or size electrode you use or where you set the controls.

This rugged new G-E welder has already received the enthusiastic approval of pipeline and construction weldors, foremen, and superintendents. Test it yourself and take advantage of its many advanced design features . . . new engine slow-down control to save fuel and oil while not welding; heavy gauge metal construction (16-gauge canopy, ¼-inch crossbars) to withstand rough field conditions; non-projecting generator protected by full length canopy; and many others.

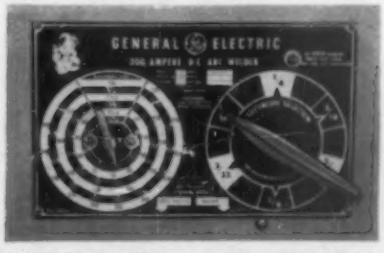
Contact your nearby G-E Welding Distributor (he's listed in the yellow pages of your phone book) or write for bulletin GEC-1333, Section 714-4, General Electric Co., Schenectady 5, New York.

Progress Is Our Most Important Product

GENERAL ELECTRIC

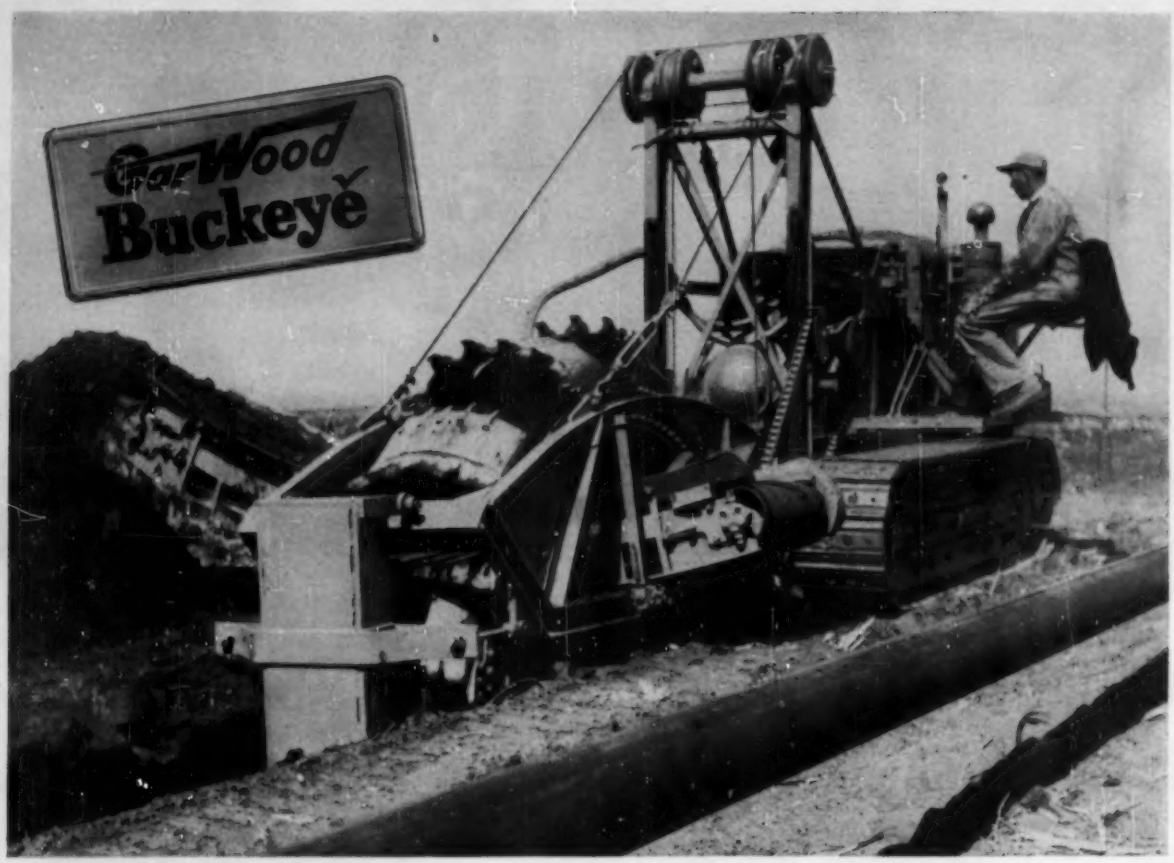
FIELD-TESTED DESIGN of new G-E 200-amp welder solves old and costly load drop-off problem in construction welding.

OSCILLOSCOPE shows 200-amp welder delivers steady output, full heat at full load.



EXCLUSIVE ELECTRODE SELECTOR, CURRENT DIAL—Dual controls make current control easier and more accurate, eliminate guesswork in setting and resetting.

Hydraulics in the 308 boost production



Adjust for changing digging conditions hydraulically from the operator's seat!

Ditch production goes up when you put a new job-proved Gar Wood-Buckeye 308 on the line! *Exclusive line hydraulic wheel hoist* positions digging wheel faster, more accurately. *Exclusive hydraulic conveyor drive* provides three discharge speeds in either direction . . . instant adjustment to handle any volume of spoil independent of any other function. No complicated shifting, no need to stop digging wheel or crawlers. Both wheel hoist and conveyor drive are independently controlled from the operator's seat. *Tractor-type crawlers* on the 308 are strong and reliable . . . assure trouble-free service.

These and other 308 features mean smooth, low-cost ditching . . . more ditch per dollar with the greatest return on your capital investment. They also mean longer life, less maintenance and less downtime. These advantages explain why pipeliners expect and get *more* for their money in Gar Wood-Buckeye ditchers. See for yourself. Ask your dealer to show you the model 308. Ask him, too, about the full range of factory options that can tailor it to your particular application and soil conditions.

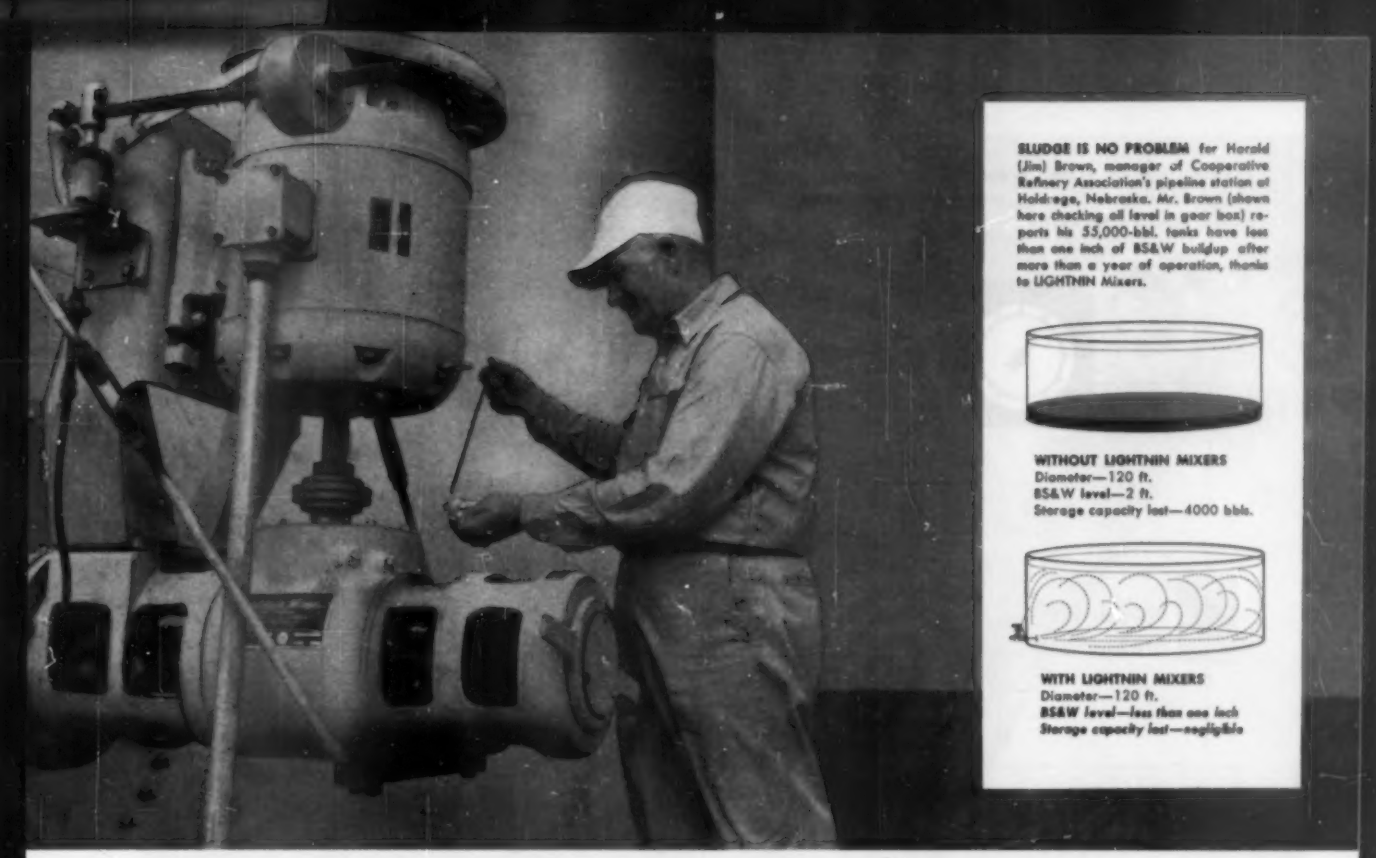
GAR WOOD INDUSTRIES, INC.

Wayne, Michigan • Findlay, Ohio

Plants in Wayne and Ypsilanti, Mich.; Findlay, Ohio; Mattoon, Ill.; Richmond, Calif.

Gar Wood Truck Cranes | Gar Wood Winches | Gar Wood Excavators | Gar Wood Tractor Equipment | Gar Wood-St. Paul Hoists & Bodies

STRAIGHT, CLEAN DITCH, cut by a Gar Wood-Buckeye 308, has fewer sags and overbends... permits faster lowering-in.



SLUDGE IS NO PROBLEM for Harold (Jim) Brown, manager of Cooperative Refinery Association's pipeline station at Holdrege, Nebraska. Mr. Brown (shown here checking oil level in gear box) reports his 55,000-bbl. tanks have less than one inch of BS&W buildup after more than a year of operation, thanks to LIGHTNIN Mixers.

WITHOUT LIGHTNIN MIXERS
Diameter—120 ft.
BS&W level—2 ft.
Storage capacity lost—4000 bbls.

WITH LIGHTNIN MIXERS
Diameter—120 ft.
BS&W level—less than one inch
Storage capacity lost—negligible

Is sludge hogging your tank capacity?

Cooperative Refinery Association cleans tanks by flipping a switch. So can you.

Sludge is a tank hog. It eats up valuable tank capacity you badly need for crude. It's a messy tenant, too, and cleaning up after it is a costly, dirty job.

Rid your tanks of sludge, and you add as much as 12% more capacity to your pipeline stations.

Cooperative Refinery Association brings crude oil from Wyoming to its pipeline station at Holdrege, Nebraska, stores it in two 55,000-bbl. tanks. When the crude moves on to the refinery at Phillipsburg, it leaves a minimum of BS&W in the tanks. In more than a year of operation, scarcely an inch of sludge has accumulated in either tank.

Simple method pays off

Secret? Cooperative Refinery Association equipped each tank with a LIGHTNIN Side Entering Mixer. When temperature falls below 70°, these mixers go to work for about four hours a day. They keep bottoms stirred, prevent oil from congealing. When the oil moves on, each tank is ready to take on a new supply—without cleaning—and at full capacity.

LIGHTNIN Mixers are keeping storage tanks free of sludge at many pipeline stations, increasing storage capacity, eliminating downtime for cleaning, making every barrel in every tank merchantable crude oil.

Here's why you can't lose

You take no risk when you order a LIGHTNIN. Every one is unconditionally guaranteed to perform its job—or your money back.

Learn how LIGHTNINs can solve your sludge problems, make your tanks work harder, cut your costs. Call in your LIGHTNIN representative, or write us today.

Lightnin® Mixers

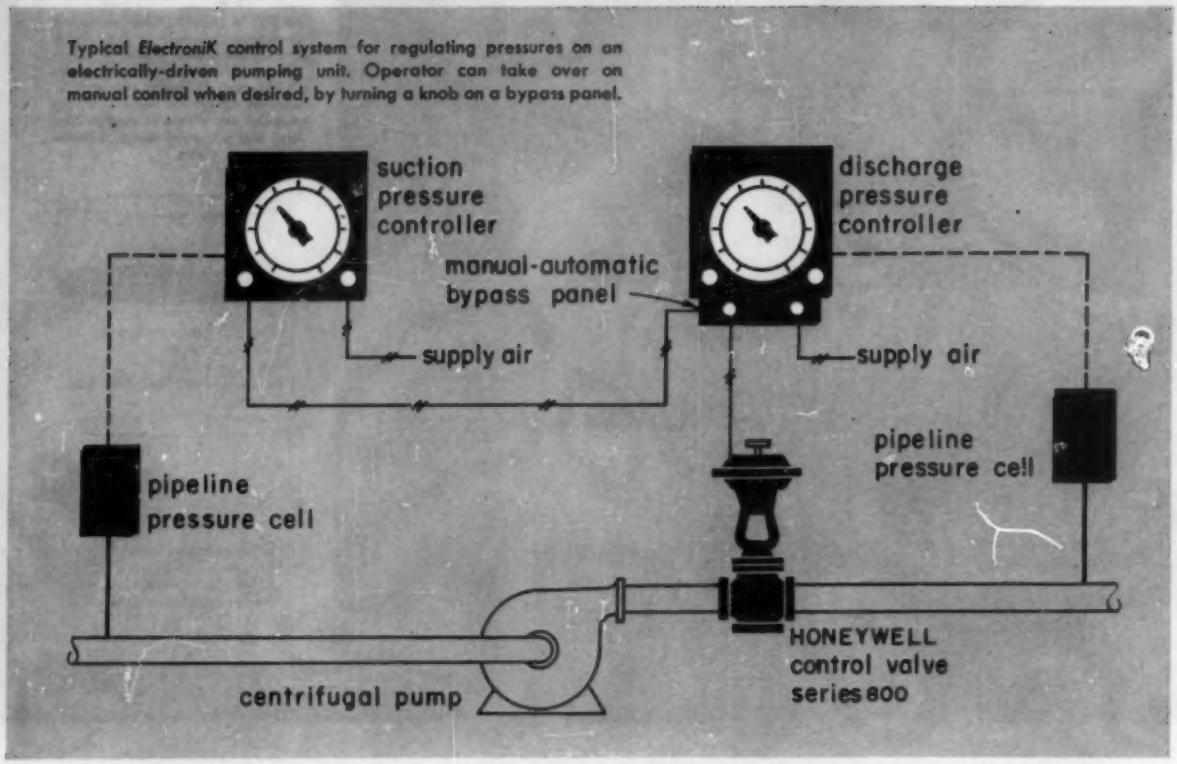
MIXCO fluid mixing specialists

Get these helpful facts on BS&W control and LIGHTNIN Mixers. Check, tear out and mail to us today with name and company address. Free—no obligation.

- ☐ B-503 Illustrated bulletin on BS&W control
- ☐ B-104 20-page catalog fully describing LIGHTNIN Side Entering Mixers
- ☐ B-107 Mixing Data Sheet
- ☐ B-110 Condensed Catalog describing LIGHTNIN Mixers of all types
- ☐ B-111 Bulletin describing LIGHTNIN rotary mechanical seals for extra-low-cost mixing

MIXING EQUIPMENT Co., Inc., 127-F Mt. Read Blvd., Rochester 11, N. Y.

In Canada: Greey Mixing Equipment, Ltd., 100 Miranda Avenue, Toronto 10, Ont.


Typical ElectroniK control system for regulating pressures on an electrically-driven pumping unit. Operator can take over on manual control when desired, by turning a knob on a bypass panel.
suction pressure controller
discharge pressure controller
manual-automatic bypass panel
supply air
supply air
pipeline pressure cell
pipeline pressure cell
HONEYWELL control valve series 800
centrifugal pump

Balance station pressures with fast, dependable *ElectroniK* control

For precise, dependable control of pumping pressures, put *ElectroniK* instruments to work in your pumping stations. This modern instrumentation gives the *extra* performance that spells high throughput . . . trouble-free operation.

Pressure measurement is all-electronic, instantaneous. Strain gage pressure cells, in the upstream and downstream piping, are the sensing elements. In a typical system, as diagrammed above, two *ElectroniK* instruments with *Air-O-Line* pneumatic proportional-plus-reset control actuate the Honeywell pipeline control valve. Either instrument takes over control as needed, to position the valve for desired suction and discharge pressures.

TROUBLE-FREE. No worries about dirt, dust and dampness. Maintenance saving features include such design details as totally enclosed balancing motor . . . non-clogging single air control restriction . . . sealed, liquid-filled control unit. Main components of the instrument are designed for years of service . . . can be replaced in seconds if necessary.

PRECISION . . . PLUS SENSITIVITY. Instruments are calibrated within limits of plus or minus 0.2 percent of full scale span.

For a discussion of how *ElectroniK* control can be applied in your pumping stations, call your local Honeywell sales engineer . . . he's as near as your phone.

MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division*, Wayne and Windrim Avenues, Philadelphia 44, Pa.—in Canada, Toronto 17, Ontario.

MINNEAPOLIS **Honeywell**
BROWN INSTRUMENTS
First in Controls

IT'S NEARING COMPLETION...
PACIFIC NORTHWEST PIPELINE'S
"SCENIC INCH"

Winding across New Mexico's deserts, climbing the snow-capped Colorado Rockies and ending at last in the evergreen country of Oregon and Washington . . . Pacific Northwest Pipeline Corporation's 2300-mile "Scenic Inch" is being rushed to completion.

This $209,000,000 pipe line project will soon deliver over 343,000,000 cu. feet of natural gas per day to aid the expanding economy of the Northwest.

Working closely with Pacific Northwest Pipeline Corporation on the "Scenic Inch" is Kaiser Steel—a major supplier of line pipe on this project.

Next time you are ordering line pipe, think of Kaiser Steel. Rely on Kaiser Steel quality and service to add dollars to your operating profits.

Kaiser Steel

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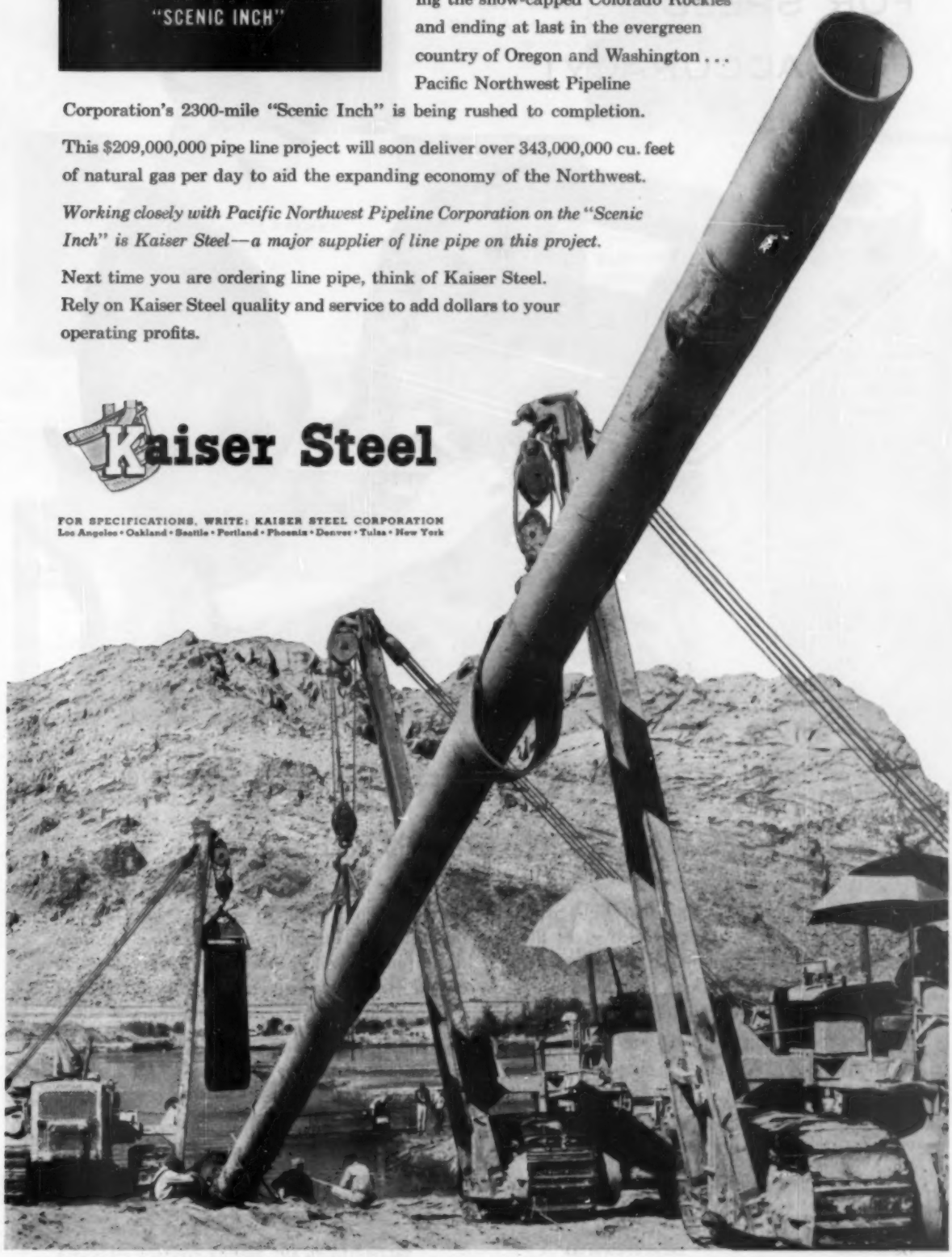

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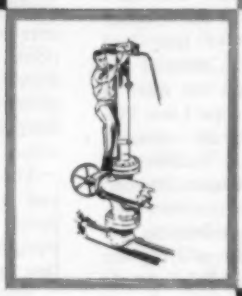

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EXCLUSIVE

Remote Controlled, Unattended Pump Stations Highlight Modernization

Paul R. Madden

Assistant Chief Electricial Engineer, Great Lakes Pipe Line Company, Kansas City, Missouri

IN August, 1955, Great Lakes Pipe Line Company completed rebuilding of its "East Line System". The East Line stations were part of the original system installed in 1931 and had reached obsolescence. Additional capacity was also required for moving product to the Badger Pipe Line System. In extent, this program consisted of replacing the entire facilities at Donahue, Iowa; Prophetstown, Illinois; and Lee, Illinois. The stations were converted from internal combustion engines to electric motor drives. They are fully automatic, unattended, remote controlled from Iowa City, Iowa. (Fig. 1.)

A new station was installed at Iowa City on the existing loading terminal site. The station has electric motor drives, is fully automatic with one attendant operating the local facilities as well as controlling the three remote stations.

This article describes the equipment, adaptations and operations for remote controlling pump stations as practiced by Great Lakes Pipe Line Company. References throughout are made to the "Controlling Station", representing Iowa City and the "Controlled Station", Donahue or Prophetstown or Lee.

The various aspects of the system are presented as follows: (1) Generalities of the station design; (2) Supervisory control and channeling; (3) Controls and protection at the remote stations; and (4) controlling a pump unit.

Controlled Stations

The design for the three remote controlled stations is similar. Donahue, Iowa, and Lee, Illinois, contain single pumping units operating on the 6-in. line while Prophetstown, Illinois, has one unit operating on the 6-in. line and one unit on the 8-in. line. Due to the similarity in design of the three locations, descriptions are confined to one single unit station.

Two buildings are utilized for installation of equipment. One building houses the centrifugal pump driven by a 400-hp, 2300-v, explosion proof, TEFC, squirrel cage induction motor. The motor is equipped with protective devices for bearings, stator winding, over-current and under-voltage. Additional cooling for the motor is provided with building louvers and exhaust fans switched automatically upon ambient temperature rise above an established value.

The pump is protected by bearing and case temperature devices. The pump seal is drained to a special tank equipped with float switch for operation upon excessive leakage.

Station pressures are regulated by a pneumatic instrument and diaphragm operated throttling valve. Protective devices are applied for low suction pressure and high discharge pressure. The pump unit and auxiliaries meet Class I, Group D requirements for hazardous areas.

The second building contains the 400-hp motor starter, control center for the station auxiliaries, air compressor, supervisory and battery cabinets. Area classification is non-hazardous.

Utilization voltages for the station are 2300 v for the pump motor, 120/208 v for the auxiliaries and 48 v d-c for the controls. (Fig. 2.)

Controlling Station

One building houses all of the equipment at the controlling station at Iowa City. The control room is equipped to

FIG. 1. Map shows location of Great Lakes Pipe Line Company's "East Line System" between Des Moines and Chicago. All four stations have been modernized, with the Iowa City station controlling the three unattended stations on the line east of that location.

maintain air pressure slightly above atmospheric preventing infiltration of vapors from the hazardous area of the adjacent pump room.

A console arrangement is utilized in the control room. (Fig. 3.) Control panels are provided for the three remote stations, the local main line pump units and the local tank pumps plus motor operated valves used in stream switching operations.

Panels for the three remote stations are provided with meters, push buttons and indicating lamps. The push buttons and lamps are patterned on a "mimic pipe line system" for ready and positive identification. (Fig. 4.) Telemetering and indications will be described later under supervisory control.

Supervisory Control

Supervisory Operation and Channel. Supervisory control for the remote stations is an all-relay system. Coded pulses are used for signalling alternately between the controlling and controlled stations. A definite selection code is assigned to the various functions referred to as "points". Signals are transmitted over a "Half-Duplex" telegraph channel leased from the American Telephone and Telegraph Company.

The three channels radiating to the controlled stations from Iowa City are derived in a number of ways as telephone company practice and facility may permit. The channels terminate at each end with a sixty milliampere loop either grounded or ungrounded, as required, for circuit protection and performance.

This minimum type of channel is satisfactory since the pulse rate frequency is low (15 per sec) and the intelligence pattern for controlling a pump unit is very adaptable. There is no compromise however, where circuit reliability is concerned.

The supervisory control relays are standard telephone type. They are enclosed in dust-proof cases for panel mounting. At the controlled station, the interposing relays, No. 201-208, are general purpose 48-v d-c- heavy duty, since their function is to connect the controlled equipment to the supervisory. The auxiliary relays 50-63 used for the various protective, shut-down and indicating features are 48-v d-c. These relays are telephone type or general purpose heavy duty, dependent upon the burden requirements. (Fig. 5.)

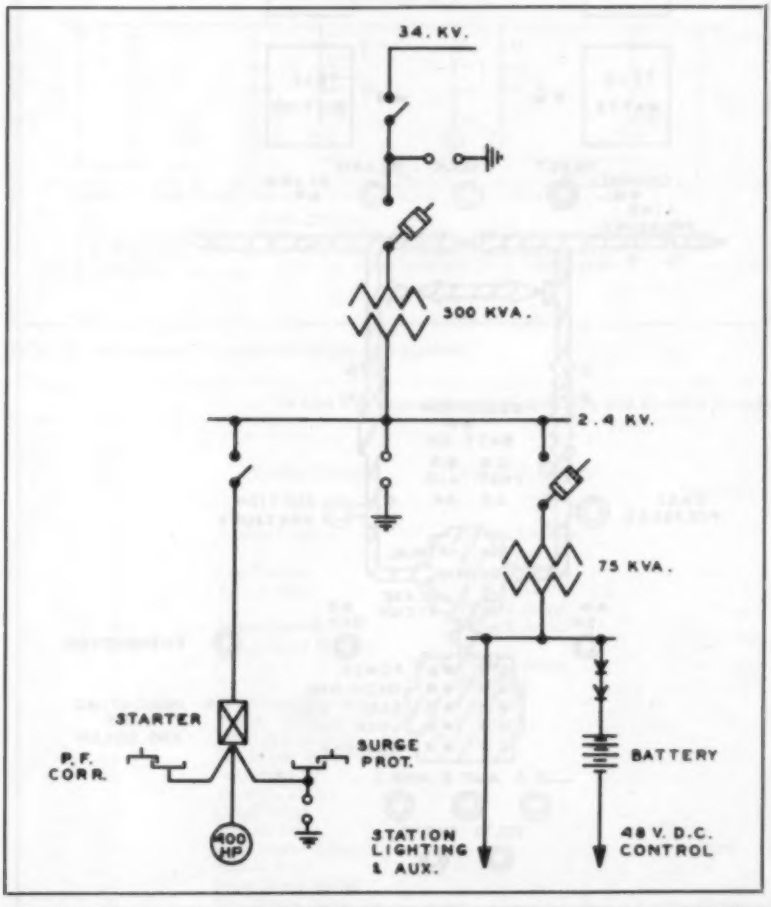


FIG. 2. Diagram shows electrical distribution at typical remote unattended station.

The Author

P. R. Madden worked in the engineering department of a privately-owned electric utility company before joining the engineering department of Great Lakes Pipe Line Company in 1947. He now holds the title of study engineer serving as assistant chief electrical engineer and is engaged in work on all elements of the electric power system.

Briefly, the supervisory control operates in the following manner. The attendant at the controlling station pushes the selector key. The equipment operates to select the unit at the pump station and also to check the selection. If the selection has been checked, the interposing relay will be energized closing a contact in the master relay circuit. The master relay in energized and initiates the starting sequence.

Contacts of the auxiliary relays change positions in the supervisory control circuits, (Fig. 5) and the supervisory operates changing lamp indications at the controlling station. The supervisory equipment automatically resets. A more detailed description of the control operations will appear under "Remote Starting of Pump Unit."

Indications — Controlling Station. Blue and amber lamps are used to indicate suction valve, pump motor supervisory and discharge valve operations. References to Table I will reveal these functions as supervisory point numbers 17, 18 and 19 respectively. Red and green lamps indicate remote alarm indications. Again referring to Table I, the alarm indications are assigned as supervisory point numbers 1, 3, 4, 6, 9, 10, 11, 12, 13, 14 and 16. An audible alarm is associated with the visual indications.

If the attendant is originating a start or stop operation and an alarm occurs, the alarm signal is delayed but not lost. After the attendant has completed his operation, the indicating lamps will change from green to red and the audible alarm sounded. An "alarm" key is provided to silence the alarm bell. A "reset" key is used to restore the equipment to the normal at-rest position.

Telemetering-Controlling Station. Upon starting the pump unit, the station discharge pressure will be transmitted, remaining continuous until the

channel is taken over for other intelligence. To selectively telemeter the other quantities (amps, volts, watts, suction pressure, case pressure) the respective metering push button must be operated and maintained. (Fig. 4.) A white lamp associated with the push button will light indicating that the quantity has been checked. The value will be metered as long as desired by maintaining the metering key. When the key is released, the equipment will automatically reset.

Station Control and Protective Equipment

Pressure Control. A method for automatically controlling or maintaining station pressures within operational limits is important for all pump stations. A dependable method is doubly important for unattended stations.

For pressure regulation, Great Lakes Pipe Line Company employs a double duty pneumatic control instrument in conjunction with a diaphragm-operated regulating valve. The valve is located on the discharge side of the pump.

Air supply for the controller is 20 psi taken from the station air line through a regulator located at the instrument. Instrument air is furnished only while the pump unit is operating by controlling a solenoid valve in the air line with an auxiliary contact from the motor starter contactor. Twenty seconds after the pump unit starts, the pressure regulating valve will begin to open. In approximately 90 seconds, the valve will open to a point representative of station by-pass pressures. From this point there is a gradual opening of the valve to meet the desired station discharge pressure in the region of 1000 psi. The time consumed to reach the desired point of control is 5 to 6 minutes.

Sequence Control For a Pump Unit. In order to start a pump unit, a series of operations must take place. This series of operations, termed sequence control, is supervised as "equipment failure" (Point 9, Table I).

The sequence is started by originating the opening of the motor operated suction valve. When the suction valve reaches an intermediate point of opening, the pump unit motor is started.

Upon starting the pump unit motor, air is admitted to the pressure controller and simultaneously the motor operated discharge valve starts to open.

Approximately 20 seconds after the pump unit is started the pressure regulating valve will begin to operate. When the discharge valve is fully open, the sequence is considered complete consuming aproximately 70 seconds in time.

Normal performance of the equip-

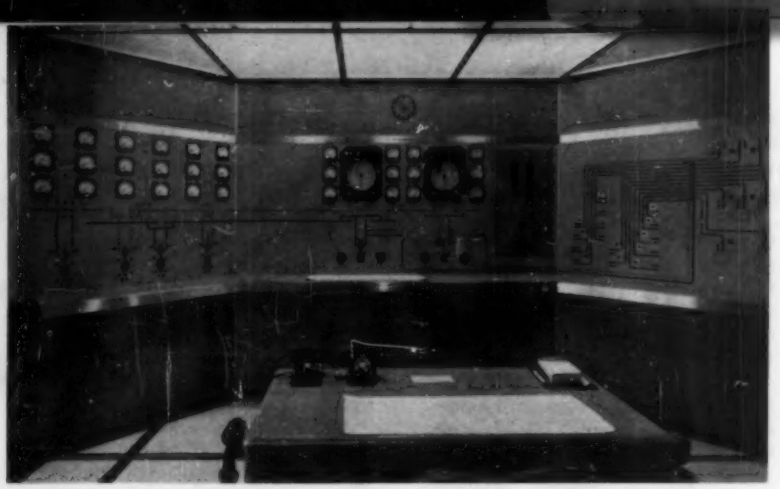


FIG. 3. Console in controlling station at Iowa City gives operator complete view of system status through both "mimic system" panel and telemetering indicators.

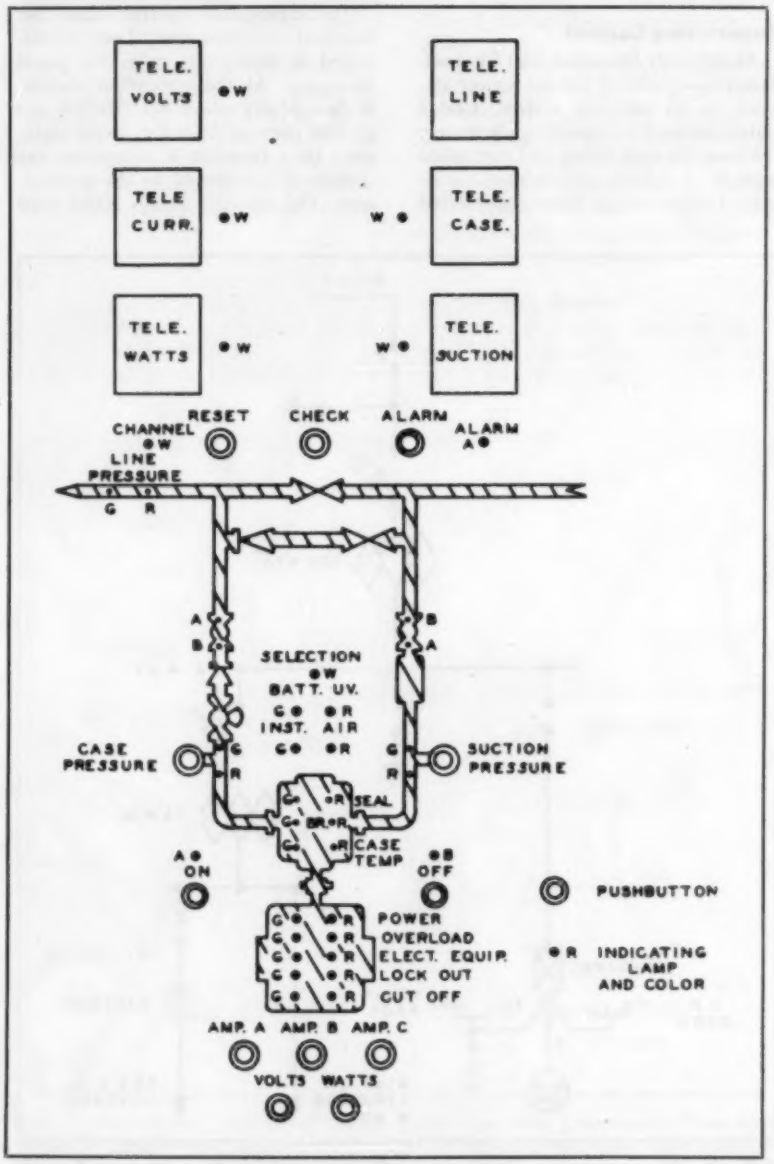


FIG. 4. Typical console panel and indications that are shown.

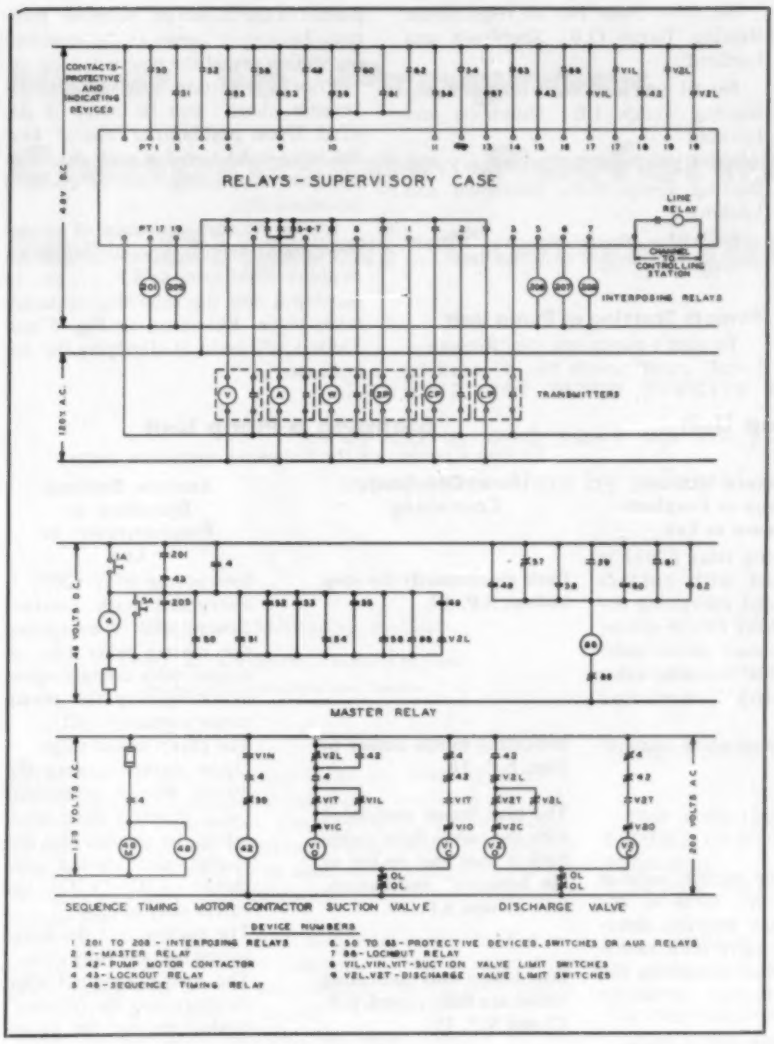


FIG. 5. Schematic diagram of single unit control.

ment within the starting sequence permits opening of the associated protective switch contacts. In event abnormal performance of the above equipment takes place, the associated protective switch contact will remain closed.

Upon "timing out" of the sequence relay No. 48, (Fig. 5) the master relay No. 4 will be de-energized shutting down the unit. The controls will be locked out necessitating inspection and clearing of trouble. The "lockout relay" No. 86 must be hand reset.

Protective Devices

Protective devices installed with the pump unit are single and double pole explosion proof switches. Other devices located in the control room are general purpose switches or relays. Since several contacts are required for each function, a protective switch or relay contact is used to energize a multiple contact auxiliary relay.

The protective devices are utilized to perform the supervisory and control functions shown in Table I. Some of the devices are grouped to create a single "point" on the supervisory control. The grouping consists of the motor bearing plus pump bearing temperatures, motor over-current plus motor stator winding temperature and starter door interlock plus sequence timing relay. For the purpose of this discussion, the protective devices are numbered from 50 to 63 inclusive. The device numbers, their supervisory point numbers and functions follow.

No. 50 — Point No. 1, Low Suction Pressure, Shutdown

No. 51 — Point No. 3, High Discharge Pressure, Shutdown

No. 52 — Point No. 4, A.C. Undervoltage, Shutdown

TABLE I. Supervision, Telemetering and Control Functions for one Unit

SUP. POINT NO.	SUPERVISION	TELEMETERING	CONTROL FUNCTIONS		
			NORMAL	ABNORMAL	
				Shutdown	Lockout
1	Suction Pressure	Suction Pressure	—	Low	—
2	—	Case Pressure	—	—	—
3	Line Pressure	Discharge Press.	—	High	—
4	A. C. Voltage	A. C. Voltage	—	Low	—
5	—	Phase A Amps	—	—	—
6	Motor Current	Phase B Amps.	—	Over-Current	—
6	Motor Stator Winding	—	—	High Temp.	—
7	—	Phase C Amps.	—	—	—
8	—	Kilowatts	—	—	—
9	Equipment Failure	—	—	Inc. Sequence	Inc. Sequence
10	Bearing Temperatures	—	—	High	High
11	Pump Seal Leakage	—	—	Excessive	Excessive
12	Pump Case Temperature	—	—	High	—
13	Instrument Air	—	—	Low	Low
14	Battery Voltage	—	—	—	—
15	Cutoff Switch	—	—	—	—
16	Lockout Relay	—	—	—	—
17	Close Master Relay	—	Start	—	—
17	Suction Valve	—	—	—	—
18	Pump Motor Starter	—	—	—	—
19	Trip Master Relay	—	Stop	—	—
19	Discharge Valve	—	—	—	—
*	Continuous Indication				

No. 53 — Point No. 9, Starter Door Interlock, Shutdown and Lockout

No. 54 — Point No. 12, High Pump Case Temperature, Shutdown

No. 55 — Point No. 6, Motor Overcurrent, Shutdown

No. 56 — Point No. 6, High Motor Stator Winding Temp., Shutdown

No. 57 — Point No. 13, Low Instrument Air, Shutdown and Lockout

No. 58 — Point No. 11, Excessive Pump Seal Leakage, Shutdown and Lockout

No. 59 — Point No. 10, High Motor Bearing Temp. I.B., Shutdown and Lockout

No. 60 — Point No. 10, High Motor Bearing Temp. O.B., Shutdown and Lockout

No. 61 — Point No. 10, High Pump Bearing Temp. I.B., Shutdown and Lockout

No. 62 — Point No. 10, High Pump Bearing Temp. O.B., Shutdown and Lockout

No. 63 — Point No. 14, Battery Voltage

Remote Starting of Pump Unit

To start a pump unit the "Remote—Local" cutoff switch No. 43 must be placed in the closed or "Remote" position. Indicating lamps at the controlling station reveal the position.

Prior to starting an operation, a "master check" can be made if desired. Upon pushing the "check" key, the lamp indication for each device in the controlled station will be checked automatically.

In the detailed sequence of operations, the supervisory points are shown in abbreviated form as S.P. 17, etc. In starting a unit the following sequence takes place. Reference to Fig. 5 and Table I will assist in clarifying the operations.

Remote Starting of Pump Unit

Sequence of Operations

Iowa City, Iowa Controlling	Remote Station Donahue or Prophetstown or Lee
Push momentarily the start button. S.P. 17.	Interposing relay (201) is energized with contact closing and energizing the master relay (4). A master relay contact closes energizing the suction valve "opening" contactor (V10).
The amber lamp associated with the suction valve lights giving both a blue and amber or "in between" indication. S.P. 17.	The suction valve starts to open.
	When the suction valve is within "N" turns of the fully open position, intermediate valve limit switch V1N closes energizing the pump motor contactor (42).
Indicating lamps associated with the pump motor starter change from blue to amber. S.P. 18.	The pump motor starts. *Upon energizing the pump motor contactor (42), a contact closes energizing the discharge valve "opening" contactor (V20).*
The amber lamp associated with the discharge valve lights giving both a blue and amber or "in between" indication. S.P. 19.	The discharge valve starts to open. *A 42 contact closes energizing a solenoid valve in the station air line and air is admitted to the pressure controller. The diaphragm operated pressure regulating valve starts to open.*
Amber lamp only indicating the suction valve is fully open. S.P. 17.	The suction valve becomes fully open. The torque switch opens de-energizing the "opening" contactor (V10) and the equipment is at rest.
Amber lamp only indicating the discharge valve is fully open. S.P. 19.	The discharge valve becomes fully open. The torque switch opens de-energizing the "opening" contactor (V20) and the equipment is at rest.
The starting sequence is completed.	

Stopping a Pump Unit

To stop a pump unit the following operations occur:

Iowa City, Iowa Controlling	Remote Stations Donahue or Prophetstown or Lee
Push momentarily the stop button. S.P. 19.	Interposing relay (205) is energized with contact closing and de-energizing the master relay (4). A master relay contact opens de-energizing the pump motor contactor (42).
Indicating lamps amber to blue. S.P. 18.	The pump motor stops.
The blue lamps associated with the valves light giving both a blue and amber or "in between" indication. S.P. 17 and S.P. 19.	Upon de-energizing the pump motor contactor (42), contacts close energizing the suction and discharge valve "closing" contactors (V1C) (V2C). The valves start to close.
Blue lamps only indicating valves are fully closed. S.P. 17 and S.P. 19.	The suction and discharge valves become fully closed. The torque switches open de-energizing the "closing" contactors and the equipment is at rest.

Local Control of Pump Unit

For local control of the pump unit, push buttons, indicating lamps, meters, gages and annunciator are provided. The "Remote — Local" cutoff switch should be placed in the "Local" or open position. Operating the "Start" or "Stop" push buttons will sequence the pump unit in the same pattern described above for the Remote operation.

Yes, 40 Is Considerably Less Than 4000!

It wouldn't fool a pipeliner, but it did slip by our proofreaders. In the article about M. J. Crose Manufacturing Company's ditch padder (The Petroleum Engineer, May, 1956, page D-88) the statement was made that the machine averaged approximately 40 ft of padding a day. Obviously, this was an error. The machine wouldn't have been worth writing about if it didn't do a better job than that. The figure should have been 4000 ft per day.

In case you missed the article, you may want to look it up now. It is about a new machine that sifts the fine material from the spoil bank in rocky areas to pad under, around, and over the pipe. No need to haul in dirt for that purpose. And it's economical, too!

How to Program Compressor Performance Data for Digital Computers

You can get more precise answers, a greater range of data, and save up to 95 per cent in engineering manpower time by using high speed digital calculators

Dean P. Johnson, *Engineer*
Fred E. Culvern, *Research Engineer*
Panhandle Eastern Pipe Line Company

DURING the past few years, there has been considerable use of high speed automatic calculating machines for making engineering calculations. These machines reduce the overall time of calculation or allow an exploration of a greater range of variables in a given time. They also eliminate the drudgery of a long computation and practically eliminate the human error.

The purpose of this article is to present one method of using an IBM Model No. 604 Computer for the calculation of performance data for gas compressors, and the presentation of this data in the form of curves.

The mathematical analysis, the data required by the "Tabulating Section," and the curves that are drawn from the calculated results will be presented.

No attempt will be made to justify the formula used in the calculation of the horsepower required to compress gas or the formula used to calculate the capacity of a gas compressor. The formulas used do not make any specific correction for supercompressibility (deviation from Boyles Law), but they have been found to be reasonably accurate when used in compressor calculations where the maximum discharge pressure is less than 1000 psig, and when the compression ratio lies between 1.2 and 2.5. They can be used for ratios outside of these limits, however, without incurring any serious errors. The horsepower formula used is a modified adiabatic form.

The theoretical adiabatic horsepower formula is:

$$Hp = .08584 \frac{n}{n-1} Q_0 T_s (R^{(n-1)/n} - 1) \quad \text{Equation (1)}$$

Where:

n = ratio of specific heats CP/CV

Q_0 = millions of cu ft per day at 14.73 psig and 60° F

Q_s = millions of cu ft per day at 14.73 psig and suction temperature

$= Q_0$ when $T_s = 520$ °R.

T_s = absolute temperature of gas at suction pressure °R.

To convert this to the form usually used in gas compressor calculations, divide by $Q_0\left(\frac{T_s}{520}\right)$.

$$Hp/Q_s = .08584\ (520) \frac{n}{n-1} (R^{(n-1)/n} - 1) \quad \text{Equation (2)}$$

This is the theoretical horsepower required to compress 1,000,000 cu ft of gas in 24 hr at 14.73 psig and suction temperature.

If the value of n is taken to be 1.277 this formula becomes:

$$Hp/Q_s = (.08584)\ (520)\ (4.610)\ (R^{.217} - 1)$$
$$= 205.77\ (R^{.217} - 1) \quad . \quad . \quad . \quad \text{Equation (3)}$$

The empirical formula used in this presentation is:

$$Hp/Q_s = 215\ (R^{.217} - 1) + 4R^{.8} - R^{1.25}. \quad \text{Equation (4)}$$

Any such formula or any set of data giving hp per million at given compression ratios may be used. The answers obtained are, of course, consistent with whatever data is put into the calculator.

Similarly, values for the capacity of a gas compressor cylinder may be calculated.

The theoretical capacity of a compressor cylinder is:

$$Q_s = \frac{Ev\ PD\ P_1\ 1440}{14.73\ (10)^6} \quad . \quad . \quad . \quad \text{Equation (5)}$$

Where:

Q_s = millions of cu ft per day

Ev = volumetric efficiency

PD = piston displacement in cfm

P_1 = suction pressure in psia at compressor flange

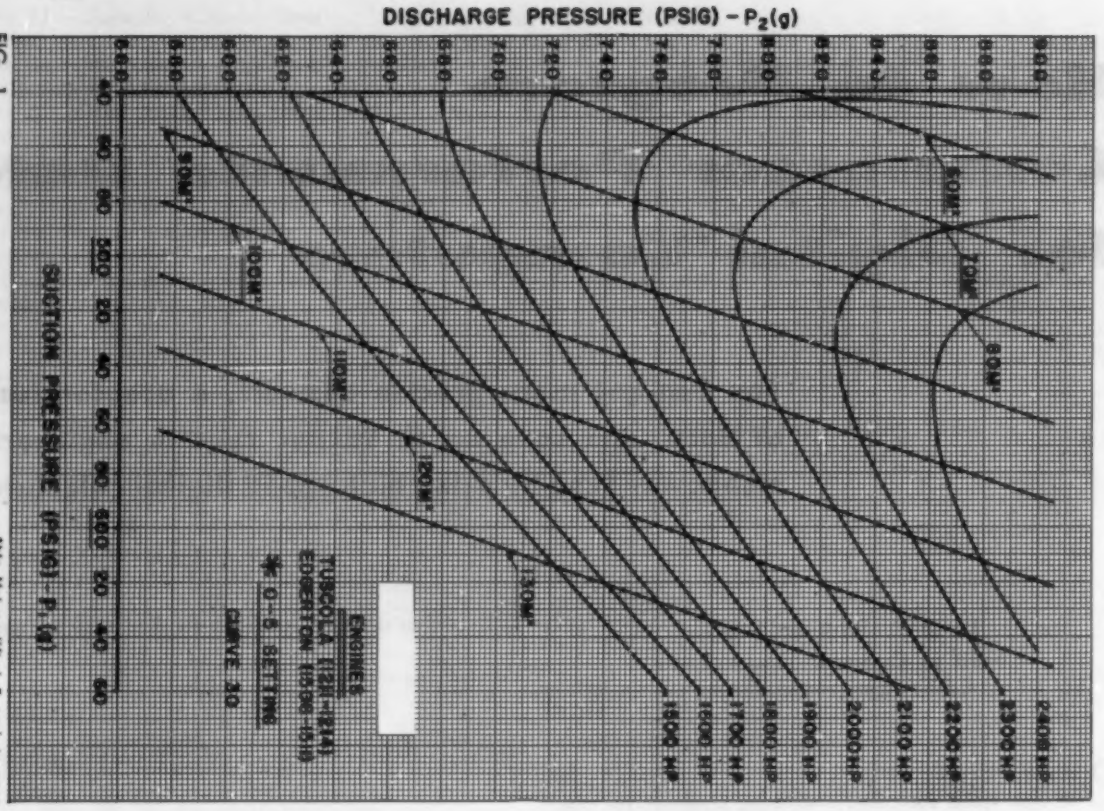
P_2 = discharge pressure in psia at compressor flange

1440 = minutes per day

14.73 = pressure base, psia

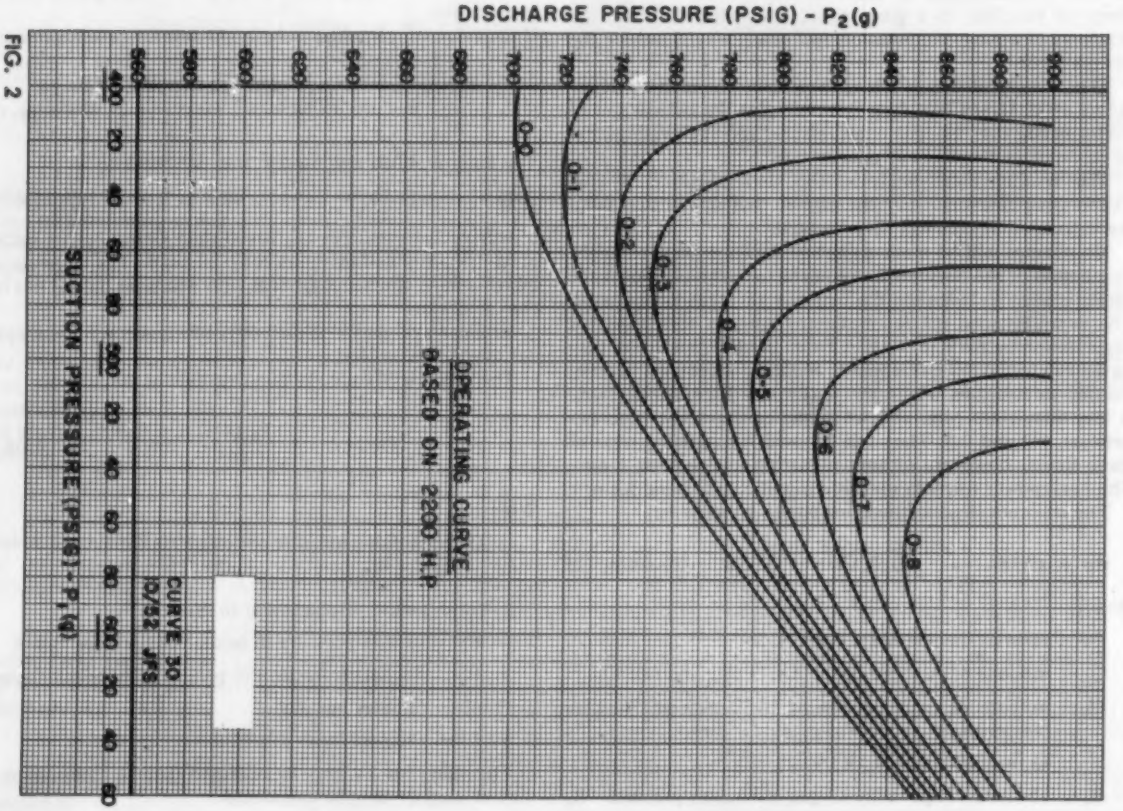
The value for Ev may be obtained from a compressor indicator card or may be calculated.

FIG. 1



*No Values lifted 5 pockets open

FIG. 2



The theoretical value for Ev under adiabatic conditions is given by:

$$Ev = 1 - C(R^{1/n} - 1) \quad . \quad \text{Equation (6)}$$

Where C is per cent clearance divided by 100.
The empirical formula used in this presentation is:

$$Ev = .98 - C(R^{.783} - 1) \quad . \quad \text{Equation (7)}$$

(Any formula giving Ev as a function of clearance and compression ratio may be used).

Substituting equation (7) in equation (5) we have:

$$Q_s = \frac{(0.98 - C(R^{.783} - 1))\, PD(P_1)\, 1440}{14.73\,(10)^6}$$

. . . . . Equation (8)

Calculations for compressor engines having multiple compressor cylinders may be made by calculating the values for each active end of each cylinder separately and adding the results to obtain values for the entire engine; or all cylinders may be taken as a unit, after first examining each active end of each cylinder to determine that the value of Ev for all values of clearance that would apply, results in a positive value of Ev.

In the procedure presented here, the entire engine is treated as a single unit located in a compressor station and the values of P_{1g} (suction pressure) and P_{2g} (discharge pressure) refer to the gage pressures existing at the points where the station piping connects to the main pipe line. An arbitrary value of 5 psi is used on both suction and discharge pressures to allow for losses between the compressor cylinders and the pressure reference points. An arbitrary value of 15 psi is used to convert gage pressures at the main pipe line to absolute pressures at that point, therefore $P_{1g} = P_1 - 10$ and $P_{2g} = P_2 - 20$.

In presenting the performance data as curves, the style of curve shown in Fig. 1 has been selected. On these curves, suction and dicharge pressure are used as the coordinates. Lines of constant horsepower and constant capacity are plotted for a given engine setting. The term "engine setting" refers to the number of cylinder ends made inactive and to the number of clearance unloaders open. This is shown on the curves by two numbers such as "0-5 setting" where the first number "0" refers to the number of ends made inactive and the second number "5" refers to the number of clearance unloaders open on the active ends.

This data can also be presented as a curve (shown in Fig. 2) using suction and discharge pressures as coordinates and plotting curves of constant engine setting for a given horsepower, usually rated horsepower or some per cent of rated horsepower at which the operator expects to run his engine.

This curve can be used by the operator to set his engine without referring to the performance curves. It is also used as an index to the performance curves. Another valuable use of this curve is to show a designer the limiting combinations of pressures for which the engine can be loaded at the selected horsepower and clearance.

In setting up the equations for the IBM calculator, equations (4) and (8) are multiplied together and solved for P_1 to give the following equations.

$$\frac{Hp}{Qs}(Qs) = Hp = (215\,(R^{.217} - 1) + R^{.8} - R^{1.25})\,(.00009776)\,(.98 - C(R^{.783} - 1))\,PD\,P_1$$

. . . . . Equation (9)

Solving for P_1:

$$P_1 = \frac{HP}{.00009776\ PD\ (.98 - C\,(R^{.783} - 1))\ (Hp/Qs)}$$

. . . . . Equation (10)

Let this value of P_1 be called P_{1h} for reference purposes, then:

$$P_{1gh} = P_{1h} - 10 \quad . \quad . \quad \text{Equation (11)}$$

From equation (8),

$$P_1 = \frac{Q}{(.98 - C\,(R^{.783} - 1))\,(.00009776)\,PD} \quad . \quad \text{Equation (12)}$$

Let this value of P_1 be called P_{1q} to distinguish it from the value obtained in equation (10), then:

$$P_{1gq} = P_{1q} - 10 \quad . \quad . \quad \text{Equation (13)}$$

An examination of these equations shows two terms that are difficult to calculate on the 604 calculator. These are the Hp/Qs function and $(R^{.783} - 1)$, both functions of R only. To simplify the calculations, these terms are evaluated for specific values of R, and the results, together with the constants .98 and .00009776, are transferred to a master deck of tabulating cards for permanent reference.

TABLE I. IBM code for calculating horsepower and capacity curves

R	HP/Qs	$R^{.783}-1$
1.2	12.050	0.1535
1.25	14.130	0.1909
1.3	16.140	0.2281
1.35	18.097	0.2649
1.4	19.999	0.3014
1.5	23.647	0.3737
1.6	27.112	0.4449
1.7	30.413	0.5151
1.8	33.565	0.5845
1.9	36.585	0.6530
2.0	39.483	0.7207
2.1	42.270	0.7877
2.2	44.956	0.8540
2.3	47.550	0.9197
2.4	50.050	0.9847
2.5	52.490	1.0492

Equations (10) and (11) can now be solved for values of P_{1gh} at specific values of R by substituting appropriate values of Hp, PD, C, Hp/Qs, and $R^{.783} - 1$.

Equations (12) and (13) can also be solved for values of P_{1gq} in a similar manner by substituting values of capacity Q, C, $(R^{.783} - 1)$, and PD.

The step by step procedure for evaluating equations (10), (11), (12) and (13) and plotting the results as performance curves follows:

(1) Each term to be handled by the IBM calculator is given a term designation for reference purposes. The letters A through T have been used to designate the various terms.

(2) These terms are then described, and the decimals and significant figures to which they are to be worked are determined.

(3) The term designations, term descriptions, and the significant figures that we have used in our work are given in the following table:

Data transcribed on the tabulating cards

Term designation	Definition		Decimals and significant figures
R	Compression ratio		X.XX
S	Engine setting designation		X.XX
T	Engine designation for reference		XX.X
A	Constant		0.00009776**
B	Piston displacement (PD)		XXXX.X
C	Clearance ratio (C)		.XXXX
D	Constant		98**
E	$R^{-.286}-1$		X.XXXX**
F	Hp/Qs		XX.XX**
G	Hp		XXXO.
H	Capacity		XXX.
I	(A)(B)		.XXXXX
J	(C)(E)		.XXXXX
K	(D-J)		.XXXX
L	(I)(K)		.XXXXX
M	(F)(L)		X.XXXX
N	(G/M)		XXXX.
O	(N-10)	(P_{1gh} eq.11)	XXXX.
P	(H/L)		XXXX.
Q	(P-10)	(P_{1gq} eq.13)	XXXX.

Note that term N is the solution of equation (10), O is the solution to equation (11), P is the solution of equation (12), and Q the solution to equation (13).

(4) The terms A through H plus R, S, and T are transcribed to a deck of tabulating cards.

(5) The terms I through Q are calculated on the 604 calculator. The procedure for transcribing and calculating the data follows:

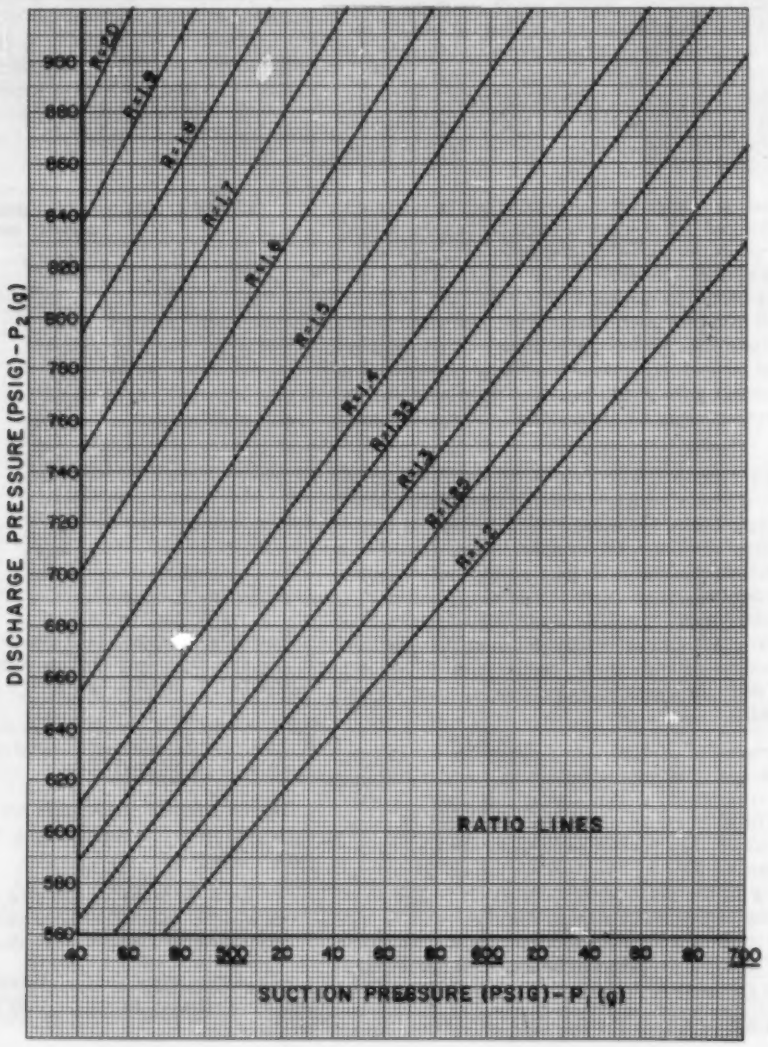
(a) A deck of tabulating cards is key punched for each engine type number T and displacement B together with each combination of setting designation S and clearance ratio C.

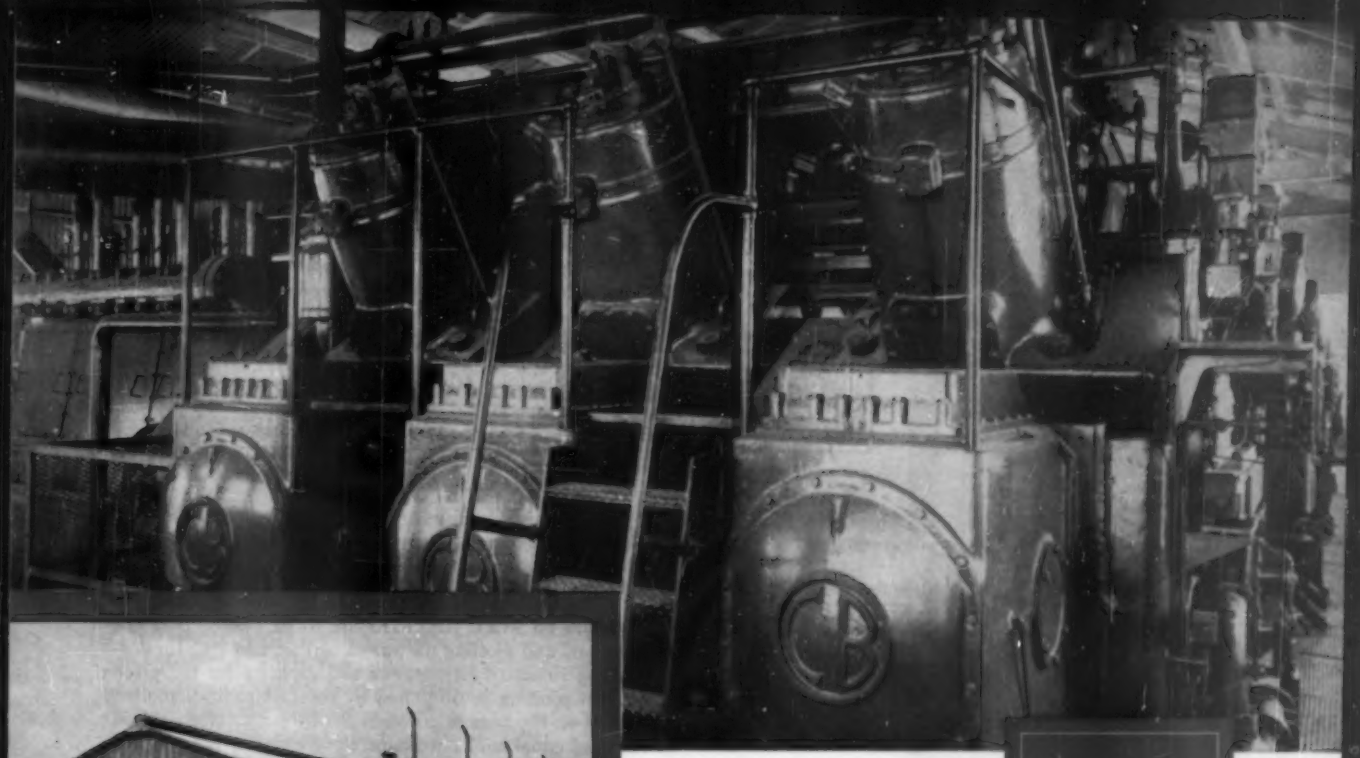
(b) A second deck of tabulating cards is key punched with combination values of horsepower G and capacity H.

(c) The permanent master deck referred to above containing values of A, D, E, and F for all values of R is sorted for the values of R stated for the problem.

(d) All the data on the above cards are then reproduced for each ratio R involved, each combination of S and C involved and each combination of G and H involved. This is done in two steps. First, combine the data in (a) and (c) into a deck. This then becomes the final working deck for the problem involved.

FIG. 3





Line-up of 6-cylinder Cooper-Bessemer V-angles in one of the pumping stations serving a large water-flooding recovery project.

A typical exterior view of one of the pumping stations.

Another Example of Efficient Power at Lower Cost

How COOPER-BESSEMER V-ANGLES *help collect a PLUS bonus...in oil*

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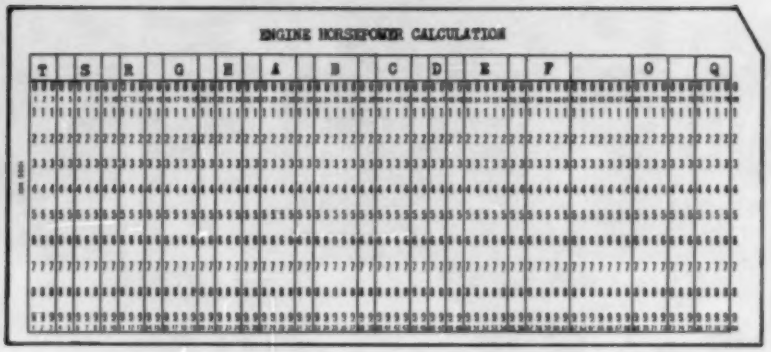
FIG. 4



(e) The working deck is then processed through a type 604 calculator to evelop values of O and Q.

(f) The cards are then sorted on the following fields:

(1) R, Ratio
(2) G, Horsepower
(3) S, Setting

This particular sorting procedure is very advantageous, as it allows the graphs to be plotted in a systematic manner.

(g) The tabulated report as shown in Fig. 5 is then prepared on the printer.

(6) A typical problem as it is usually presented to the tabulating section follows: (It is assumed that the master reference deck referred to above has been previously prepared.)

Given:

T = 30.0

R all values from 1.2 to 2.4

B = 1213

S, C, G, & H (see tabulation)

S	C	G	H
000	.5000	1500	060
001	.5284	1600	070
002	.5751	1700	080
003	.6035	1800	090
004	.6503	1900	100
005	.6787	2000	110
006	.7254	2100	120
007	.7538	2200	130
008	.8005	2300	140
		2400	150

For each combination of S and C any number of combinations of G and H may be used. The above values have been selected for this problem and G and H are arbitrarily paired as shown.

Find:

Values of P_{1gh} and P_{1gq} correlated to values of compression ratio, capacity, horsepower, and engine setting. (See Fig. 5).

(7) Having obtained the report shown in Fig. 5, the data can be plotted to yield curves as shown in Figs. 1 and 2.

(8) To aid in plotting the data, a master chart, shown in Fig. 3, is first prepared by plotting lines of constant R vs suction and discharge pressure. Note that P_{1g} and P_{2g} are gage pressures as defined above, and R is based on absolute pressures at the compressor.

(9) The final charts are prepared by superimposing the graph paper on which the charts are to be plotted over the master chart and plotting the values of P_{1gh} and P_{1gq} for corresponding values of horsepower and capacity for the given ratio. This plotting is simplified by the fact that all plotted values fall on the lines of constant R of the master chart and all values of equal horsepower and equal capacity are grouped together on the printed report as described in (f) above.

(10) The charts of Fig. 1 and Fig. 2 are plotted from the same data by changing the parameters. It will be noted, for example, that the 0-5 curve in Fig. 2 is the same as the 2200 hp curve in Fig. 1.

Summary

In conclusion, it may be said this method has saved our company many valuable engineering man-hours, provided data over a greater range than was feasible earlier, and increased the precision of the answers. The number of engineering man-hours now required for calculation is only 5 per cent of that required earlier.

The authors gratefully acknowledge the assistance of Kenneth A. Johnson, head of the Tabulating Section, in the preparation of this paper.

★ ★ ★

FIG. 5. Engine operating curve calculation — Number 30.

Pocket setting	Horsepower	Ratio × 100	P_{1gh}	Capacity	P_{1gq}
0/05	2000	120	793	100	474
0/05	2000	125	695	100	489
0/05	2000	130	626	100	503
0/05	2000	135	575	100	520
0/05	2000	140	540	100	540
0/05	2000	150	482	100	573
0/05	2000	160	451	100	614
0/05	2000	170	431	100	662
0/05	2000	180	423	100	716
0/05	2000	190	421	100	779
0/05	2000	200	427	100	841
0/05	2000	210	440	100	941
0/05	2000	220	461	100	1048
0/05	2000	230	491	100	1180
0/05	2000	240	532	100	1348
0/05	2100	120	833	110	522
0/05	2100	125	731	110	538
0/05	2100	130	658	110	555
0/05	2100	135	605	110	573
0/05	2100	140	547	110	595
0/05	2100	150	507	110	631
0/05	2100	160	474	110	677
0/05	2100	170	453	110	720

P 615.55

This single-unit booster station is operated by supervisory control over microwave. From left to right are the outdoor substation, control building, microwave building and tower, and pump building.

Remote Station Operation Grows

Rise in cost of station attendance has resulted in rapid spread of practice—Here is how the stations are designed

W. A. Derr
Switchboard Engineering Department
Westinghouse Electric Corporation

M. A. Hyde
Industry Engineering Department
Westinghouse Electric Corporation

ALTHOUGH the initial application of supervisory control to pipe line pumping was made 25 years ago, only recently have the costs of station attendance risen to a level where operating companies have taken a lively interest in its possibilities.

Installations have been made, or equipment put into manufacture, within the last 4 years for remote operation of at least 60 electrically powered pumping stations on pipe lines transporting crude oil or refined petroleum products. An unprecedented number of future projects are under active study.

Because of the relatively long distances between pipe line pumping stations, economics dictates the use of supervisory control for remote operation to minimize control channel requirements.

A pipe line, in its simplest form is a conduit with a means for causing flow of fluid from the initial to the terminal end; flow results from pressure developed by a pump at the initial end. In a crude oil or product line, each flow rate (for a given liquid and pipe size) requires application of a certain pressure per mile of pipe. The total pressure that must be developed by the pump is the pressure drop per mile multiplied by the length of pipe in miles, plus the positive or negative static pressure corresponding to the difference in elevation of the two ends of the line. Thus, the length of line that can be served by one pumping station is determined by the desired flow rate, the difference in elevation of the ends, and the limiting working pressure for the pipe.

To accomplish long-distance transportation, several pipe line sections are installed in series, each section with a pumping station at its initial end. In the past, oil was delivered from the terminal end of each section into a tank, from which it was pumped into the next section of line. Modern practice is to operate the sections end-to-end without tankage, as illustrated diagrammatically in Fig. 1.

The throughput of a line can be increased by employing greater total impelling pressure. As the discharge pressure at a pumping station is limited by allowable pipe stress, however, additional throughput is obtained by inserting pumping stations at intermediate points between terminal stations. Such booster stations may develop any pressure up to the allowable pipe pressure. Booster stations at midpoints, which develop the same pressure as the original stations, are shown in Fig. 1B. The total impelling pressure is doubled, and the increased flow is the same as would result if this pressure were all applied at the initial station, the new pressure gradient having a steeper slope (greater psi drop per mile).

Remote Operation

Two-Station Link. Most frequent type of remote operation is the two-station link shown in Fig. 1A, where booster stations 1A and 2A are re-

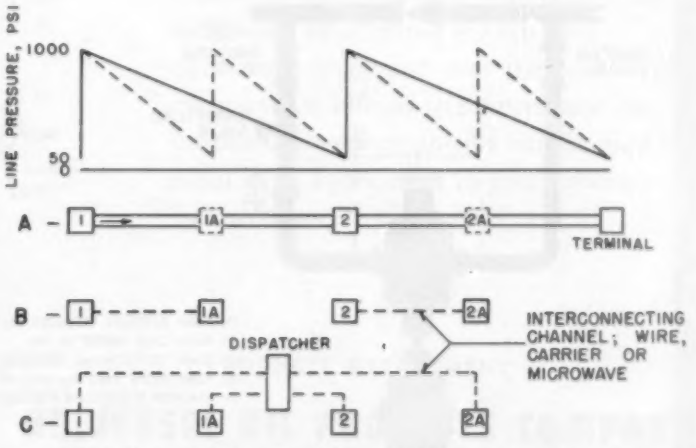


FIG. 1. If discharge pressure of a simple system (A) with one downstream station is limited to 1000 psi, booster stations will double total impelling pressure. Remote stations can be operated by two-station links (B) or from a centralized dispatching office (C).

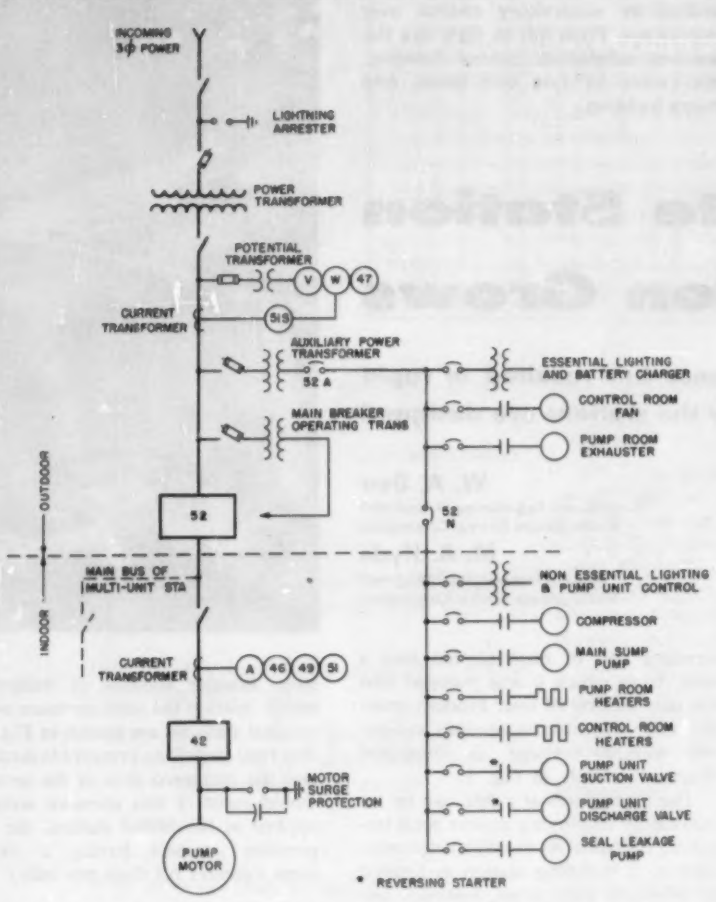


FIG. 2. Typical single-line diagram for a simple single-unit pump station.

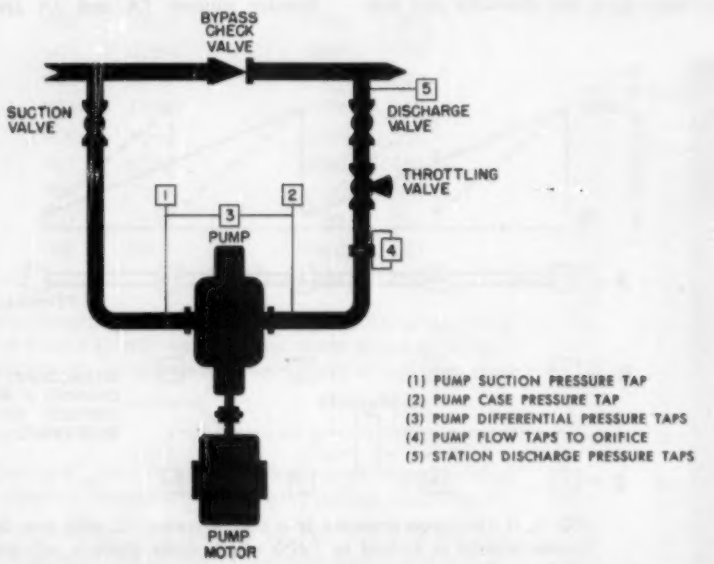


FIG. 3. Piping and valve arrangement for single-unit pump station.

motely operated, each from a neighboring attended station. Usually the controlling station is upstream, because from changes in his local operation the attendant can readily anticipate the conditions that will follow at the next station downstream. This arrangement is particularly applicable where electric booster stations are inserted between existing stations for increased line capacity. In a series of pumping stations over level terrain, a throughput increase of about 50 per cent is attained by doubling the number of stations, yet with no increase in the number of station operators.

Centralized Remote Control. In this arrangement, the control for a complete series of stations is carried out from a single location, as shown in Fig. 1B. The controlling location can be initial or terminal station, but if the system is to be centrally controlled it is logical to place this responsibility directly under the dispatching personnel. This location is normally at the administrative headquarters, which is likely to be near the center of the line. (Fig. 1C)

Equipment Arrangement. A typical single-line electrical diagram for a simple single-unit remotely controlled pumping station is shown in Fig. 2. The piping and valve arrangement for the same station is shown in Fig. 3.

The scheme shown employs a main circuit breaker placed outside the station building and the hazardous area. Principal control equipment is installed in a pressurized room of the station. For safety, station ventilation is operable even when the main breaker is open. By connecting the auxiliary-power transformer on the supply side of the main breaker, this breaker may be opened without interrupting service to the control room and pump room fans, battery charger, and necessary lighting. Station isolating valves and local residential load likewise may be served. All equipment supplied from this so-called "essential" auxiliary bus and located within the station building is explosion-proof.

Remaining auxiliaries are supplied through a segregating breaker. Their control equipment is installed in the pressurized control room along with the main pump control. The segregating breaker is arranged for tripping simultaneously with the main breaker in an emergency such as might cause the control room atmosphere to become hazardous.

The main breaker feeds the pump unit (or pump unit bus) and typically is equipped with relaying for phase reversal, voltage failure, and overcurrent. A voltmeter and wattmeter indicate power supply and load conditions.

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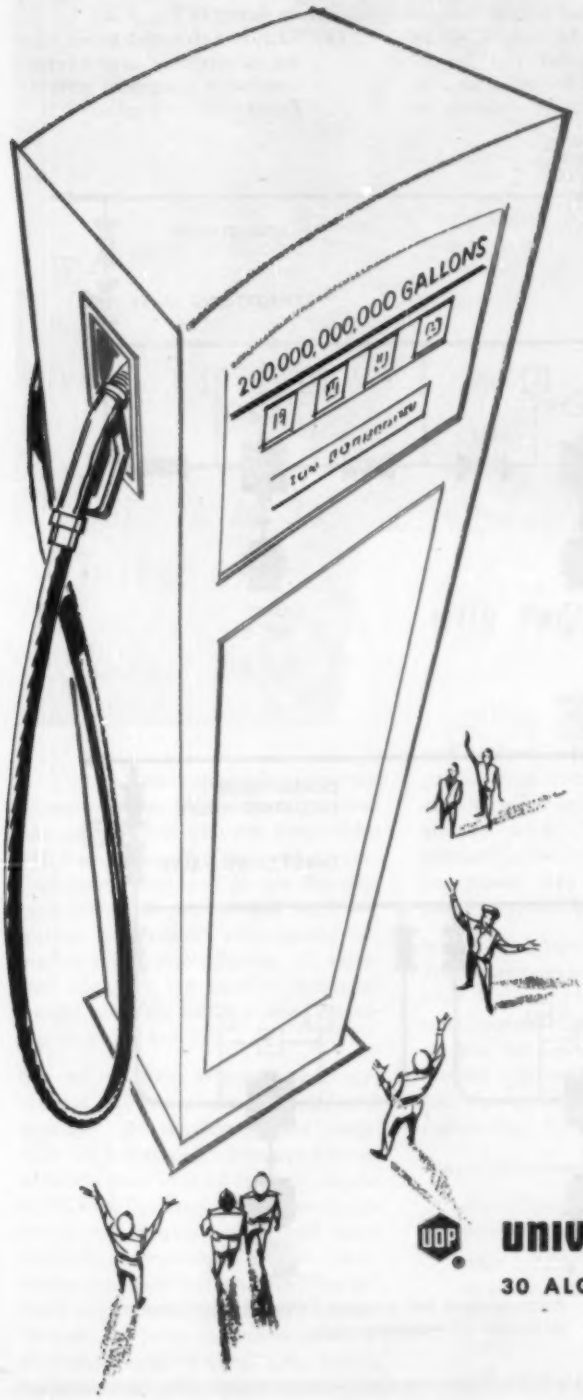

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An operating transformer on the supply side of the breaker supplies power for breaker closing, and a battery provides direct current for breaker tripping. The main breaker has connected to its load side the main pump-motor starting equipment, with surge protection capacitor and arrester.

In a single-unit station employing full-voltage starting of the main unit, the layout shown in Fig. 2 may be modified by combining the main breaker function with the motor breaker, thereby eliminating a breaker. Some installations, particularly new stations designed for unattended operation, have all the control equipment installed in a single location, sufficiently separated from the pumping equipment to be outside of the hazardous area. No hazard is introduced in the control room when its ventilation is interrupted, and the segregating breaker is omitted.

The main circuit breaker may be manually controlled either locally or remotely. If the breaker is tripped by a protective relay, it must be manually reclosed. A condition for closing the breaker is that power supply voltage and phase sequence be normal. As an alternative, the breaker can be arranged for automatic reclosing for conditions other than those resulting in lockout.

Sequence Control of Pump Units

When a pipe line pumping station is remotely operated, an automatic-sequence control system for the pump units must be established. That is, the operating procedures for starting or stopping a pump unit should be carried out in a prescribed order.

A typical automatic starting sequence for the simple single-unit pump station, as shown in Fig. 2, is:

(1) Suction valve and pump venting valve opened, and necessary ventilation equipment started
(2) Pump motor energized

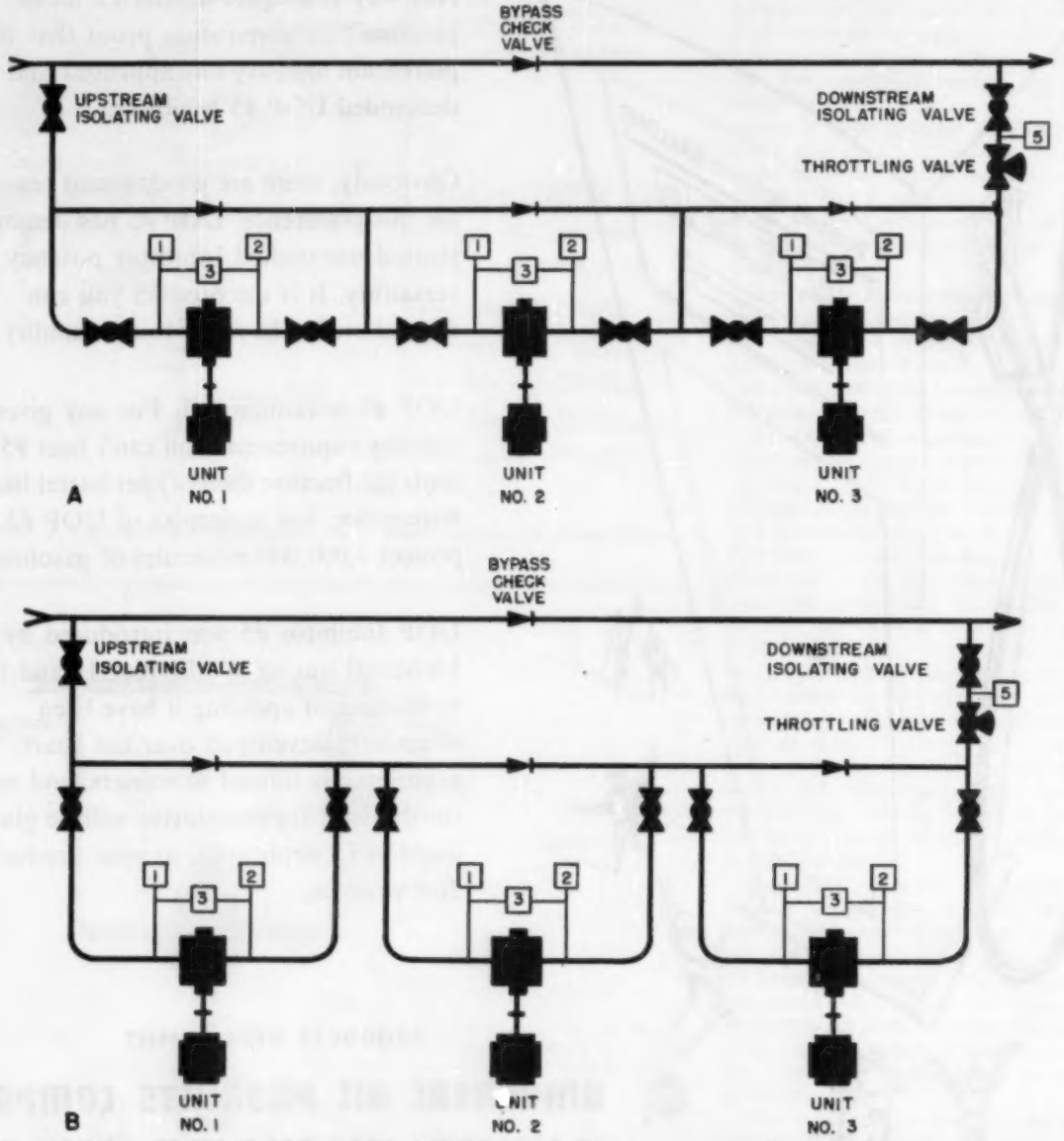

FIG. 4. Typical piping diagrams for multi-unit stations: Minimized station piping and pressure drop (A) is commonly used for crude oil lines; arrangement for product lines (B) maintains a minimum of contamination.

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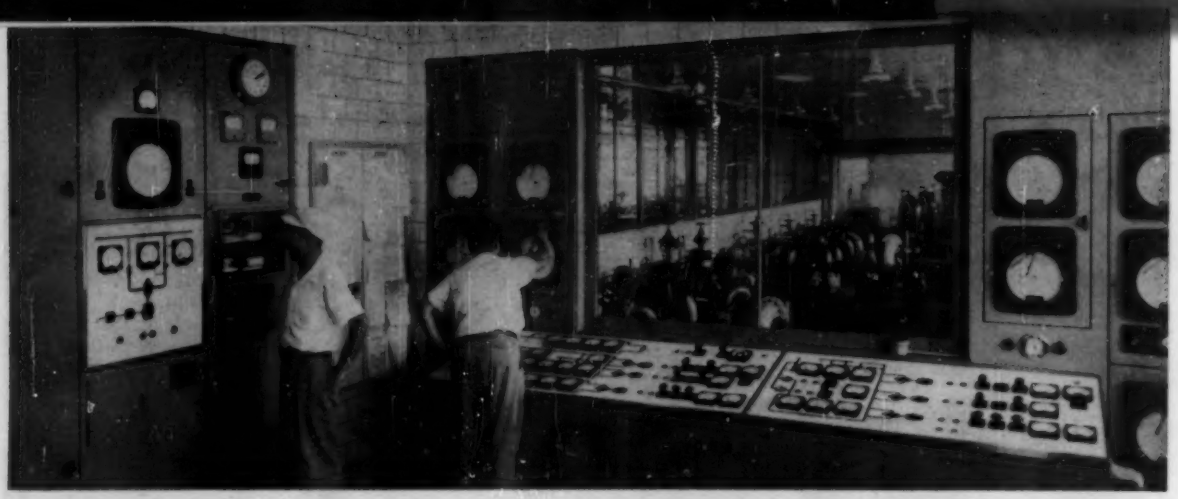


Control room of a large multi-unit pump station. Pushbutton sequence control for seven local units is provided on central control console. Diagram panel, at left, controls booster station 56 miles downstream by supervisory control.

(3) Discharge valve opened and pump venting valve closed.

For stopping:

(1) Pump motor and its associated ventilation equipment de-energized

(2) Discharge valve closed

(3) Suction valve closed.

There are individual variations from these procedures, as many installations do not require venting, and others close the suction and discharge valves simultaneously when stopping the unit. In a remotely controlled station, the starting sequence can be initiated by a start pushbutton at the remotely located controlling station or at the local station start. The stopping sequence can be initiated by remote and local stop pushbuttons, or by operation of protective devices.

Coordination With Hydraulic Control

With constant-speed motors, which are ordinarily employed for reasons of simplicity and adaptability to hazardous atmosphere, regulation of the station incremental pressure to suit line requirements is usually accomplished by some form of throttling valve in the station discharge, as shown in Fig. 3. This throttling valve is under pneumatic control by pressure-regulating elements responsive to station suction and discharge pressures and arranged to keep these pressures within prescribed limits under varying line conditions.

Stations having more than one unit usually employ pumps connected in series with a single throttling valve on the downstream side of the final pump, as shown in Fig. 4. Shutdown in response to abnormal pressure is desirably sequential; this will minimize hydraulic shock and keep as much of the station in operation as practical when shutdown of some of the units would correct the abnormal pressure. Shutdown due to low suction or high case pressure in the individual pump is accomplished in the same manner as for a single-unit station, by pressure switches installed on each side of each unit, at tap points 1 and 2 shown in Fig. 4.

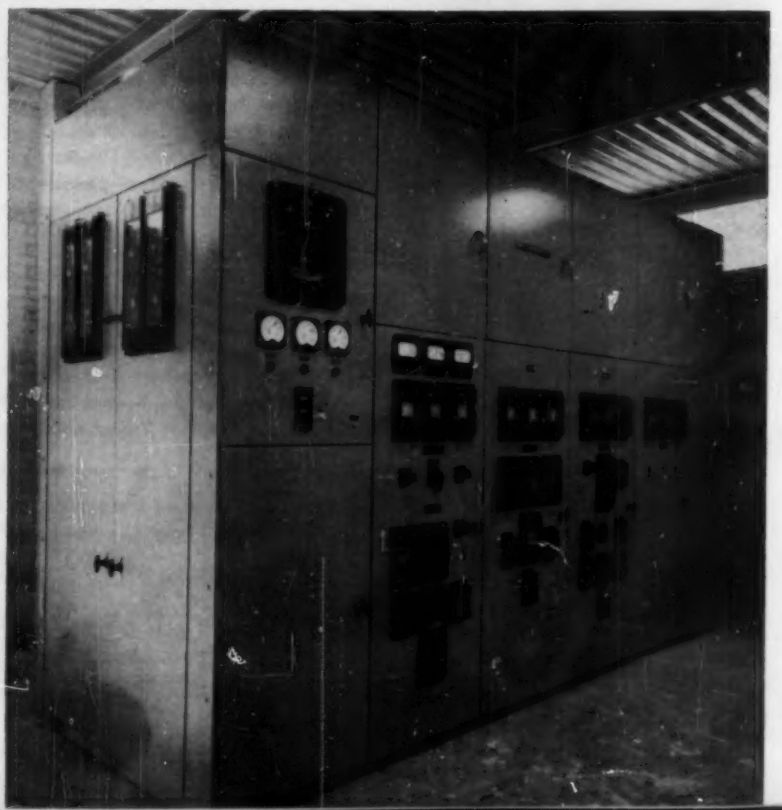
As low, station suction pressure is reflected on the suction side of the upstream operating unit, this arrangement provides inherently sequential shutdown in the event of low, station suction pressure. High case pressure is sensed initially on the downstream unit, and results in sequential shutdown in the reverse order to that for low, station suction pressure.

Shutdown due to high, station discharge pressure must be actuated by a single pressure switch tapped to the downstream side of the station throttling valve (tap point 5 of Fig. 4). In many stations, this switch shuts down all units simultaneously; however, sequential shutdown on high, station discharge pressure can be accomplished.

Pump Station Protection

In all electric-equipment installations, protection against abnormal operation or equipment failure is impor-

Supervisory control equipment is generally installed with the motor-control equipment and in new stations is often made an integral part of the switchgear assembly, as shown here for a single-unit unattended pump station. The supervisory control equipment is mounted on the rear panel of the left-hand unit of this switchgear.



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tant, but in no type of installation is an adequate protective system more important than in a pipe line pump station because of the nature of the medium transported. This is particularly true for remotely operated stations where usually no personnel are present.

Protection for individual stations varies according to the basic arrangement. In existing installations, the selection of protective functions has been based on individual analysis. Based on experience, protective functions can be assigned to four basic categories, which are believed to be best for the typical unattended station.

Station shutdown should result only from phase reversal or a-c undervoltage. The main circuit breaker is opened. When voltage conditions are restored to normal, the breaker is reclosed either manually or automatically, depending on the method of operation employed, and the individual pump units can then be restarted after their suction and discharge valves have closed.

Station lockout should result from from a-c overcurrent, battery undervoltage, low, instrument air pressure, high level in main sump, or unsafe atmospheric condition in control room. The main breaker is opened and locked out; it can be reclosed only when the lockout device is manually reset.

Unit shutdown consists of stopping a pump and closing its suction and discharge valves in the normal manner. Conditions for pump unit shutdown are low suction pressure, high pumpcase pressure, high discharge pressure, motor overtemperature, pump case overtemperature, or motor-phase current unbalance. The pump can be restarted when the condition corrects itself.

Unit lockout should result for motor overcurrent, incomplete starting sequence, seal failure, motor bearing overtemperature, or pump bearing overtemperature. The pump is stopped, and suction and discharge valves closed. The unit can be restarted only by manual reset of the lockout device.

All protective functions should be individually annunciated locally. At a remotely controlled station, the most satisfactory form of annunciator is the drop type.

Supervisory Control

Supervisory control operating over a single telegraphic-type channel performs the necessary operations, providing information on the position of apparatus, and indications and alarms for trouble conditions.

Remote operation must be effective over relatively long distances ranging from approximately 20 miles to hundreds of miles. The necessary channels for operation of pipe line pumping stations can be provided by telegraphic-type tone operating over privately owned microwave or telephone-line carrier links. In addition, individual telegraphic-type channels can be leased, or a voice channel can be leased and the necessary number of telegraphic-type channels obtained by use of audio-tone generating and receiving equipment.

The equipment in a pumping station remotely operated by supervisory control must be arranged to provide the following minimum control functions and indications of device positions:

(1) Start-stop sequence control of each pump unit
(2) Indication of stopped or running condition of pump motors
(3) Indication of open, closed, and intermediate positions of the suction and discharge valves of all pump units.

In addition, an indication of the position of the main breaker is desirable (also control of main breaker unless it is completely automatic) as well as indications of station lockout and individual pump unit lockout. A supervisory control cutoff or transfer switch is desirable at the controlled station, and the position of this switch

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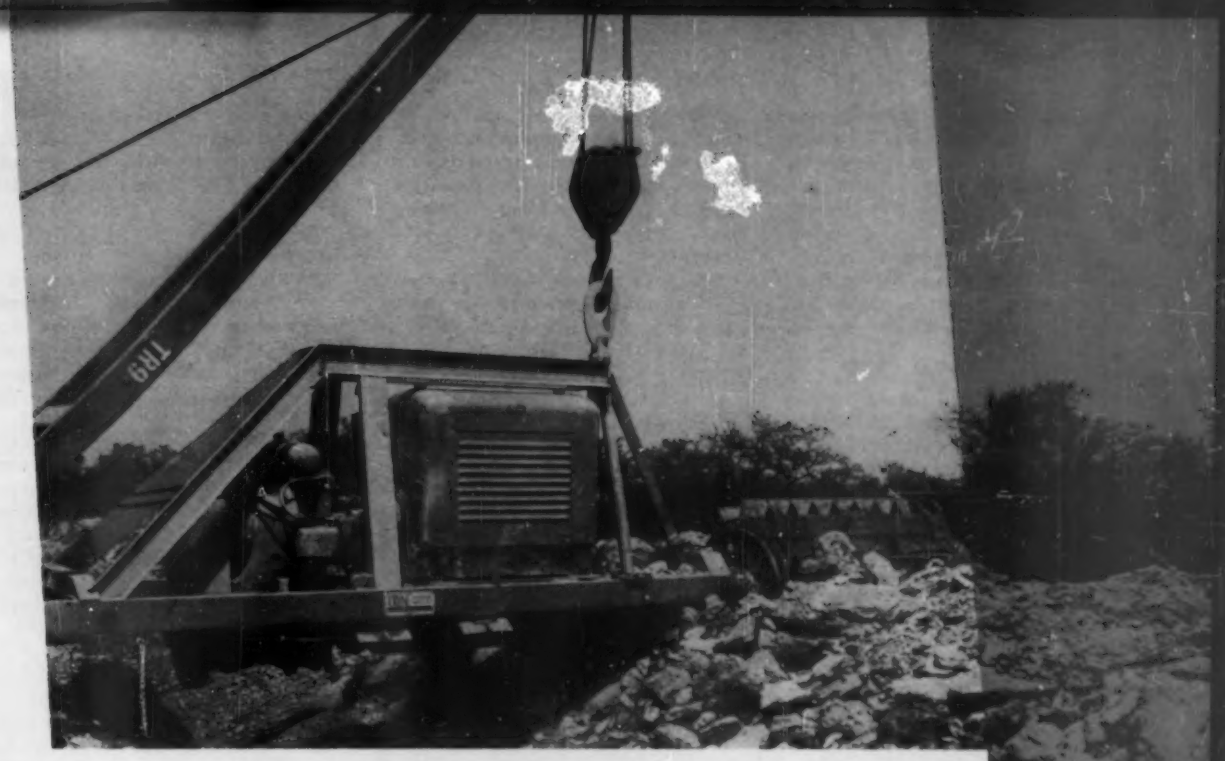

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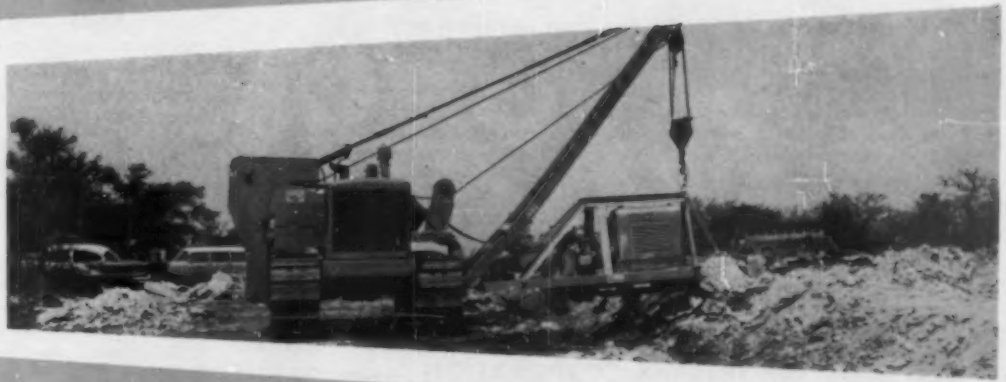

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is usually indicated at the controlling location. In some installations, control of the main sump pump is desirable. Unless completely automatic means are provided, provision for remote adjustment of the control point setting of the station discharge-pressure controller may be necessary. Where electrically operated isolating valves are employed, remote operation may be desirable.

Rather than have the starting and stopping of pump units directly under the control of a remote operator, a combined remote manual and automatic arrangement is sometimes preferable. With this type of control, the operator can stop a pump unit at any time, but he can only prepare it for starting; actual starting and subsequent stopping is then dependent on line hydraulic conditions as sensed by pressure or flow switches.

Economic considerations may prohibit individual indications over supervisory control for all protective device operations. Protective devices can be grouped in various combinations, however, to provide a relatively small number of indications that will assist in determining the type of personnel to be dispatched to the controlled station when a lockout is reported.

A typical grouping of functions for common indications for a single-unit station could fall in the following categories:

(1) Power failure
(2) Electric equipment failure
(3) Mechanical equipment failure
(4) Abnormal hydraulic conditions.

Supervisory control for pipe line pumping is usually arranged to provide the same type of operating procedures as required for local sequence control.

Telemetering

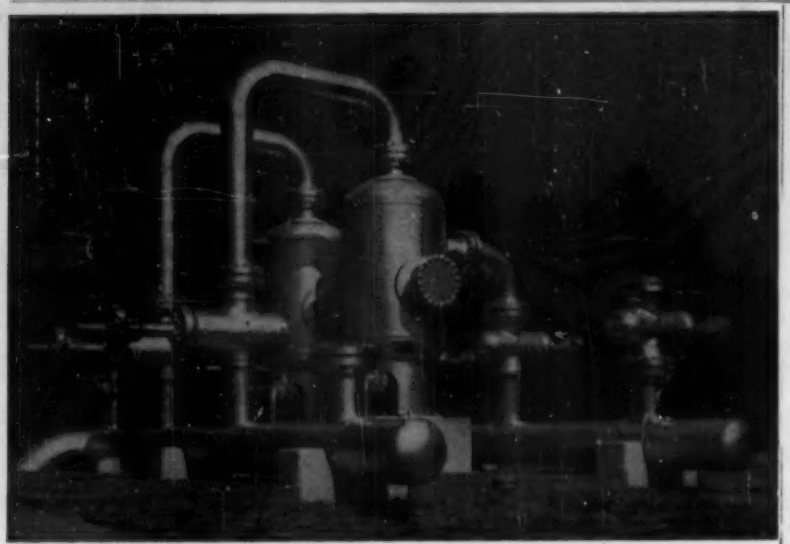
Regardless of the number of pump units in a remotely operated station, telemetered indications to the controlling location of the several hydraulic quantities is essential: (1) Initial pump suction pressure, (2) final pump discharge pressure, and (3) outbound line pressure if a throttling valve is employed.

Telemetering of flow may be desirable where flow conditions are not uniform throughout the line, as may result from deliveries at intermediate points. Although not essential for remote operation of a pump station, telemetering electrical quantities such as watts and amperes for the pump motors and volts for the station may be desirable.

Telemetering can be continuous with a separate channel for each indication, or the telemetered quantities can be indicated in consecutive order through some type of time-division multiplexing. Or, they can be selectively obtained at the will of the dispatcher through the supervisory control equipment. Economics usually favors one of the latter arrangements, although many compromises with some continuous and some selective or multiplexed telemetering, are possible.

Pulse-duration or frequency-type telemetering systems are usually employed. Pulse duration-type telemetering transmitters can be directly actuated by the hydraulic quantity or by the electric output of a transducer. The frequency-type telemetering transmitters can only be employed for hydraulic quantities through the use of transducers. The frequency-type telemetering system provides faster rate of response but requires channels capable of handling higher keying speeds.

Reliability cannot be overemphasized in the design of remotely operated stations. A full complement of devices to detect all hydraulic and electrical trouble conditions is all important. Locally actuated shutdown of the unit or station in trouble should result after a condition of trouble has been detected by one of these protective devices. Remote operation should only be employed when its functioning is coordinated to an adequate protective system.



Manifolded to provide a capacity of 200 MM SCFD at 650 psig with a pressure drop of 1.5", these Aerotec units remove both dust and liquids from the gas.

AEROTEC GAS SCRUBBERS

designed to remove solids or liquids

On this 845 mile, 30" feeder line from Louisiana to West Virginia, five compressor stations present wide variations in contamination of gas being transported.

At some stations, the scrubbing problem presented is one of dry dust removal. All others, fluid carryover requires the removal of dust and liquid. Aerotec Scrubbers for these compressor stations were designed to handle the conditions encountered at each station. Resulting gas delivered to the 8000 horsepower compressors is dry and free from abrasive dusts.

Aerotec Gas Scrubbers are noted for their ability to deliver gas, free of fluid carryover. No liquids used in the scrubbing process makes this possible. Temporary overloads of up to 100% are easily handled without efficiency loss.

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EXCLUSIVE

Submarine Lines Need Corrosion Protection

Robert C. Ledford
Operations Manager
The Marine Gathering Company

Here are the methods that The Marine Gathering Company has found successful over a period of years

THE Marine Gathering Company initially constructed gathering facilities in the Gulf of Mexico off Vermilion Parish, Louisiana, in July, 1950. At that time an 8-in. diam line approximately 9 miles long was laid directly out into the unprotected waters of the Gulf. This line brings the gas and distillate production of the Pure Oil Company to shore from the Rollover field.

To combat a possible internal corrosion problem, a sufficiently heavy wall pipe was used to provide necessary density to stabilize the installation.

This, in turn, presented the problem of suitably protecting the pipe from external corrosion, and organic attack. To provide insulation of the metal from sea-water corrosion, a double coating of coal tar enamel, using glass fabric underneath with a second wrap of glass felt (mica-coated), was placed on the pipe. After completing the construction and testing of the line it was buried 3 ft under the Gulf floor by means of jet trenching. This, it was felt, would protect the coating from organic attack.

To provide for ultimate protection in case of deterioration of the coating over long periods of exposure and the possibility of damage sustained by the coating, cathodic protection was installed on the line.

Anodes Installed

Because power was not available sacrificial magnesium anodes were used. Strings were designed that could be attached to the pipe line by brazing a heavy electrical cable to the pipe. The anode strings were then distributed adjacent to the line as indicated in an accompanying sketch. As the maximum practical potential available with magnesium-steel couple is approximately minus 1.35 volts, anode stations

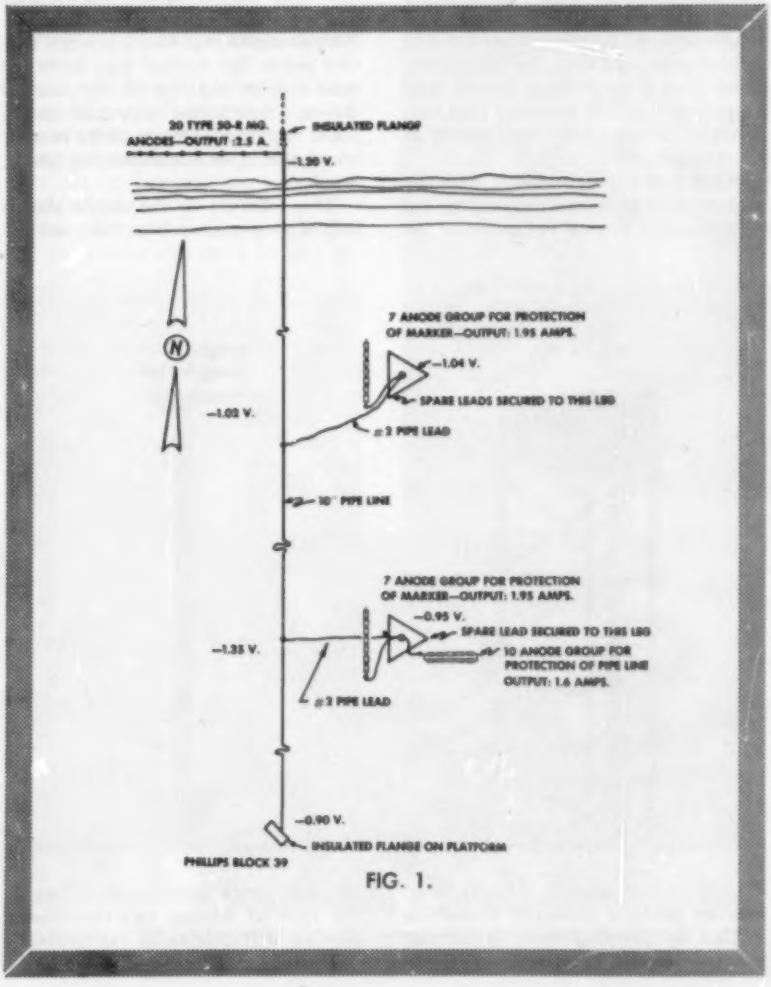

20 TYPE 50-R MG. ANODES—OUTPUT: 2.5 A.
INSULATED FLANGE
–1.30 V.
7 ANODE GROUP FOR PROTECTION OF MARKER—OUTPUT: 1.95 AMPS.
–1.04 V.
SPARE LEADS SECURED TO THIS LEG
–1.02 V.
#2 PIPE LEAD
10" PIPE LINE
7 ANODE GROUP FOR PROTECTION OF MARKER—OUTPUT: 1.95 AMPS.
–0.95 V.
SPARE LEAD SECURED TO THIS LEG
10 ANODE GROUP FOR PROTECTION OF PIPE LINE OUTPUT: 1.6 AMPS.
–1.35 V.
#2 PIPE LEAD
–0.90 V.
INSULATED FLANGE ON PLATFORM
PHILLIPS BLOCK 39

FIG. 1.

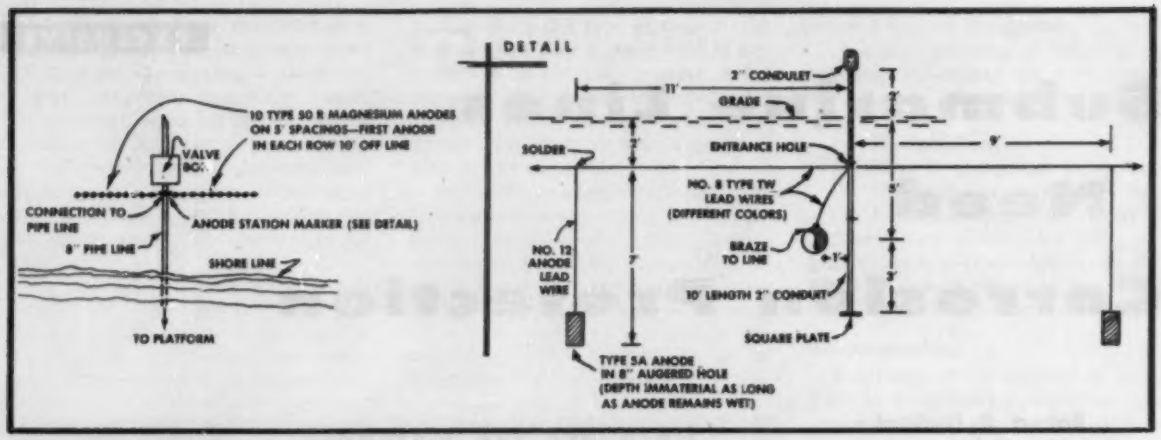

10 TYPE 50 R MAGNESIUM ANODES ON 5' SPACINGS—FIRST ANODE IN EACH ROW 10' OFF LINE
VALVE BOX
CONNECTION TO PIPE LINE
ANODE STATION MARKER (SEE DETAIL)
8" PIPE LINE
SHORE LINE
TO PLATFORM
DETAIL
2" CONDULET
11'
GRADE
SOLDER
ENTRANCE HOLE
9'
NO. 8 TYPE TW LEAD WIRES (DIFFERENT COLORS)
NO. 12 ANODE LEAD WIRE
BRAZE TO LINE
10' LENGTH 2" CONDUIT
SQUARE PLATE
TYPE 5A ANODE IN 8" AUGERED HOLE (DEPTH IMMATERIAL AS LONG AS ANODE REMAINS WET)

FIG. 2.

were established on piling markers at 6-mile intervals, with a check marker spaced equidistant between.

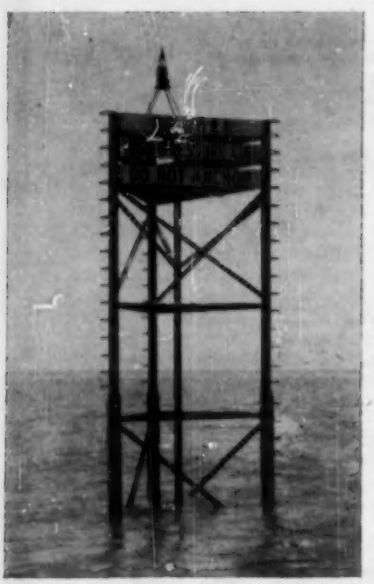
After a sufficient interval had elapsed to allow for polarization, current drains in the magnitude of 1.5 to 2.5 amp were recorded at the anode stations, with a potential of minus 1.0 to 1.10 volts at the check points. Shunts were then tied into the circuit to control current drain, which lowered potential to minus 0.95 volts and current drainage proportionately. This demand could then be used to project a life of ten years plus with average current output per anode of 0.160 amp.

This manner of installing cathodic protection was satisfactory except for one feature. Constant sea action on the cables, which were carried from the Gulf floor to the top of the markers, required that they be replaced in approximately one year, because flexing broke the copper conductor, leaving only the insulation as a tie between the two ends.

For this reason, when the company constructed its second line into the Gulf in 1953, new anode station markers were designed that had a conduit carried inside the marker legs from the mud line to the top of the marker through which the electrical cables could be carried. Details of the marker are shown in an accompanying photograph.

This addition to the anode station helped to protect cables from sea action, but upon occasion it was found that shrimp boats in dragging their nets close beside the markers were causing damage to the cables laying on the ocean floor between the bottom of the marker and the pipe line itself, which was located approximately 50 ft away from the marker. Performance of the protection system otherwise was excellent.

Plan of this system is shown in Fig. 1. Details of shore installations are shown in Fig. 2.



Typical anode station. This type of marker protects cathodic protection cables by carrying them in conduit centered in the three legs.

Original check point station. Use of this type of marker was abandoned due to difficulties in maintaining cables.

Performance Record

A number of opportunities were presented during the first three years of operation to observe the performance of this protection.

The pipe lines are insulated from the platforms and their related piping and structural members by the use of insulating flanges, sleeves, and washers. After the first line had been in operation for one year it was decided that the vertical riser leg and the seaward end of the line should be raised and inspected to observe what effect barnacle incrustation was having on the coating and wrapping. We were surprised to note that at some time during the year a storm had evidently carried a piece of heavy, water logged debris under the platform and against the pipe line, where it evidently had lodged and through sea-action had pounded off all coating for a length of approximately 6 ft. But because of our cathodic protection the exposed pipe showed a uniform deposition of calcareous material approximately 3/16 in. thick. Upon buffing this deposit from the metal the steel was found to be in excellent condition, without pitting or scaling.

Barnacle encrustation of the vertical riser seemed to present a minor problem, as there were only scattered colonies, all of which were composed of small barnacles less than ½ in. in diam. None had penetrated the coating deeply

Anodes shown suspended in plastic casing from cross-brace of platform 6 ft above sea level.

Anode cable conduit. Electrical cable connecting anodes to rectifier can be seen on pipeline riser. Hoses banded on riser are for lubricating swing joints on risers.

enough to expose metal. It is felt that the glass coating may tend to discourage growth of barnacles, because a 36-in. steel piling immediately adjacent to the pipe line is heavily encrusted with barnacles.

Rectifiers Installed in 1955

During the addition of loop lines to our system in May, 1955, it was decided that, as power had become available at the platform ends of the lines, it would be more economical to use rectifiers at the platforms and impress sufficient current at that point to carry protective potentials all the way to the shore, thus eliminating the expense and difficulty of maintaining the necessary electrical cables at intermediate points on the sea floor. We installed a 15-v, 30 amp selenium rectifier on each of the platforms connecting to main lines and tied them electrically to our operating lines, using anodes that were suspended from the platform structural members and sheathed with plastic pipe perforated for anode exposure.

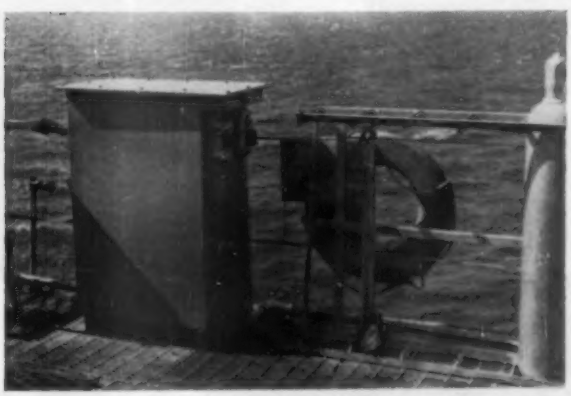
On the "A" platform of the Pure Oil Company, we are impressing negative voltages ranging from 1.25 to 1.50 volts on two field gathering lines in addition to the main 8-in. gathering line that runs ashore 9 miles away.

The insulating qualities of our wrapping materials are reflected by the fact that our potential at the beach is minus 1.05 volts. This line has been in service six years.

On the Phillips Petroleum Company-Kerr-McGee "A" platform the impressed voltage on a 10-mile 10-in. pipe line is approximately minus 1.32 volts and the potential at the beach is minus 1.15 volts.

Meters are permanently installed and tied to calomel electrodes located below the platforms at the terminus of electrical conduits put in for that purpose, so that it is possible, if necessary, to record daily readings. These meters were installed chiefly to allow us to maintain a close check on the performance of the ground bed anodes and the cables connecting them to the rectifier.

The cables are now supported by stranded monel wire to which the in-



Rectifier installation. Rectifier receives power supply from diesel generators, which provide lighting and refrigeration for platform.

Conductor conduit installation, which carries anode cables to anode hangars.

Tennessee Gas Transmission Company's

"Muskrat Line" submarines

toward completion...

The "Muskrat Line", with its feeders, covers a total of 355 miles. From point A, off the Louisiana Coast, it runs generally westward across the Mississippi River Delta and along the Louisiana coast. And at point B (Crowley, La.) it hooks up with the existing gathering system. Only the last 70 miles of the line, before it reaches Crowley, involved normal dry land construction techniques.

New 355-mile pipe line extension gets colorful name from wild swamps and marshlands it traverses. *Four-fifths of it will be laid under water.*

THE "Muskrat Line" extension is part of this company's current $56,000,000 pipe line and compressor expansion program. When completed, the program will give the Tennessee Gas system a total of more than 9500 miles of pipe line in 15 states. Average daily delivery capacity will then be 1,800,000,000 cubic feet.

A. O. Smith Corporation is proud to be a part of this new extension by furnishing the 18 and 20 inch and a portion of the 24-inch line pipe.

The purpose of this new construction is to bring important new onshore and offshore natural gas reserves to the customers of Tennessee Gas.

The magnitude of the work involved in building the "Muskrat Line" is indicated by the facts that special canals had to be dredged through the marshlands . . . special pipe-laying barges had to be built . . . and 130 navigable bodies of water had to be crossed. Completion of the "Muskrat Line" is expected by mid-summer.

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sulated electrical cables are clipped at 12 to 15 in. intervals.

These installations made it possible to eliminate intermediate anode stations and check points entirely, and, whereas the possibility of cable maintenance being required frequently has not been entirely eliminated, the observation of its performance and ease of replacing from the platforms without the necessity of hiring a diver and awaiting good weather for such work more than justifies the cost of revamping the system.

To those in the industry who have been investigating the use of polyethylene or polyvinyl tapes, it might be of interest to know that on one of our gathering lines of approximately 1½ miles long we have used poly tape with excellent results thus far. Current requirements to date have been modest and performance compares favorably with other coatings, with an apparent saving in installation labor costs to offset material cost.

A new polyethylene tape that is now available has been laminated with the outer layer impregnated with copper-bearing salts, which we propose to use on future installations, especially on vertical risers where the slowly bleaching copper will discourage marine organic attack.

In summary, it is felt that the revision of the cathodic protection system on our pipe line system to provide a current impressment point at one end of the line and a check point at the opposite end on shore, assures the engineer that his protection levels are maintained throughout the system, and makes servicing and maintenance less dependent on the vagaries of the weather. It is felt that a modification of this system would be adaptable to lines of greater length, utilizing intermediate production platforms as sheltered locations for installations, less subject to damage by marine traffic or sea-action.

* * *

The Author

R. C. Ledford, manager for The Marine Gathering Company, has had a varied career in the petroleum, petrochemical, and pipe line industry.

He began in the engineering department of the Phillips Petroleum Company after attending the Missouri School of Mines.

During World War II he was construction superintendent on one of the first 100-octane gasoline plants completed in Texas. Recently, in conjunction with his activities with The Marine Gathering Company, he has acted as a consultant on problems of design for several pipe lines and construction companies concerning submarine pipe line installations.

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EXCLUSIVE

How to Work the Revised Panhandle Formula

John F. Schomaker

L. E. Hanna

Solution of Formula

An article published in last month's issue of this magazine gave in detail the derivation of the "Modified Panhandle Flow Formula." The complete formula as shown in equation (9) accounts for difference in elevation and compressibility. For calculations requiring only a fair amount of accuracy, these two factors may be omitted from the formula. A graphical approach to the solution of the formula with those two factors omitted is presented here. The simplified formula is:

$$Q = 737\left(\frac{T_0}{P_0}\right)^{1.02} E \left(\frac{P_1^2 - P_2^2}{T_f L G^{.961}}\right)^{0.510} \times D^{2.53}$$

Where:

Q = cubic feet per day at P_0 and T_0,

T_0 = base temperature, F abs,

P_0 = base pressure, psia,

E = efficiency factor,

P_1 = upstream pressure, psia,

P_2 = downstream pressure, psia,

T_f = flowing temperature, F abs,

L = length of pipe line, miles,

G = gas gravity referred to air,

D = inside diameter of pipe, in.

This formula is quite cumbersome to use and the possibility of errors in the calculation is apparent. It is possible, however, to break the formula down into its components and to tabulate each component within the range desired for general pipe line design. The greatest advantage of this procedure is that each component is a continuous mathematical function and in tabulating values within a range, the statistical method of first, second, and third differences can be applied to the table to check accuracy of figures to the desired number of decimal places. A further advantage is that the formula solution can be rapidly obtained by multiplying together the proper values. Calculations can be arranged in columnar form for ease of checking.

When greater precision than the tabulated intervals is desired, a straight line interpolation may be used without any loss of accuracy, as all tables have intervals chosen so that the curves between tabulated points is essentially a straight line.

The equation can be separated into its components as follows:

$$Q = 737 \times \left(\frac{T_0}{P_0}\right)^{1.02} \times \left(\frac{1}{T_f}\right)^{0.510} \times \left(\frac{1}{G}\right)^{.4901} \times \left(\frac{1}{L}\right)^{.510} \times D^{2.53} \times E \times P_1^{1.02} \left(\frac{r^2 - 1}{r^2}\right)^{.510}$$

Normally T_0, P_0, T_f, and G will remain constant for a design problem, therefore, these components can be grouped together in one table. The following tables can be prepared:

(a) F_{GT_f} = Temperature-gravity function ..... Table 1

$$F_{GT_f} = 737\left(\frac{T_0}{P_0}\right)^{1.02} \times \left(\frac{1}{T_f}\right)^{.510} \times \left(\frac{1}{G}\right)^{.4901}$$

(b) F_p = Pressure function ..... Table II

$$F_p = (P_1)^{1.02}$$

(c) F_L = Pipe line length function ..... Table III

$$F_L = \left(\frac{1}{L}\right)^{.510}$$

(d) F_D = Pipe line diameter function ..... Table IV

$$F_D = D^{2.53}$$

(e) F_r = Ratio function ..... Table V

$$r = \frac{P_1}{P_2}$$

$$F_r = \left(\frac{r^2 - 1}{r^2}\right)^{.510}$$

The flow equation then simplifies to the very workable form of:

$$Q = F_{GT} \times F_p \times F_L \times F_D \times F_r \times E$$

Several examples will illustrate the use of the tables.

Example No. 1

Find the volume that can be carried in a pipe line 80 miles in length and with an inside diameter of 25.375 in. (26 in. OD).

Given:

$P_0 = 14.73$ psia

$T_0 = 60$ F or 520°R

$T_f = 60$ F or 520°R

$G = 0.650$

$E = 92$ per cent

$P_1 = 900$ psia

$P_2 = 550$ psia

Then:

$$r = \frac{P_1}{P_2} = \frac{900}{550} = 1.64$$

$$Q = F_{GT} \times F_p \times F_L \times F_D \times F_r \times E$$

TABLE I. F_{GT} = gravity-temperature function — $737.0\left(\frac{T_s}{P_s}\right)^{1.02}\left(\frac{1}{G}\right)^{1.4901}\left(\frac{1}{T_f}\right)^{0.510}$

Temperature, F	Gravity 0.600	0.610	0.620	0.630	0.640	0.650	0.660	0.670	0.680	0.690	0.700
35	1515.9	1503.7	1491.8	1480.1	1468.7	1457.6	1446.7	1436.1	1425.7	1415.6	1405.6
40	1508.3	1496.1	1484.2	1472.6	1461.3	1450.3	1439.4	1428.9	1418.5	1408.4	1398.5
45	1500.5	1488.4	1476.6	1465.1	1453.8	1442.8	1432.1	1421.6	1411.3	1401.2	1391.4
50	1492.8	1480.8	1469.0	1457.6	1446.4	1435.4	1424.7	1414.2	1404.0	1394.0	1384.2
55	1485.4	1473.4	1461.7	1450.3	1439.2	1428.3	1417.6	1407.2	1397.0	1387.1	1377.3
60	1478.4	1466.4	1454.8	1443.4	1432.3	1421.5	1410.9	1400.5	1390.4	1380.5	1370.8
65	1470.9	1459.1	1447.5	1436.2	1425.1	1414.3	1403.8	1393.5	1383.4	1373.5	1363.9
70	1463.8	1452.0	1440.5	1429.2	1418.2	1407.5	1397.0	1386.7	1376.7	1366.9	1357.3
75	1457.1	1445.3	1433.8	1422.6	1411.7	1401.0	1390.6	1380.4	1370.4	1360.6	1351.0
80	1449.9	1438.2	1426.8	1415.6	1404.7	1394.1	1383.7	1373.5	1363.6	1353.9	1344.4
85	1443.1	1431.4	1420.1	1409.0	1398.2	1387.6	1377.2	1367.1	1357.2	1347.5	1338.1
90	1436.7	1425.1	1413.7	1402.7	1391.9	1381.4	1371.1	1361.0	1351.2	1341.5	1332.1
95	1429.8	1418.3	1407.0	1396.0	1385.3	1374.8	1364.5	1354.5	1344.7	1335.1	1325.7
100	1423.3	1411.8	1400.6	1389.7	1379.0	1368.5	1358.3	1348.4	1338.6	1329.1	1319.7
105	1416.8	1405.3	1394.2	1383.3	1372.7	1362.3	1352.1	1342.2	1332.5	1323.0	1313.7
110	1410.6	1399.2	1388.1	1377.3	1366.7	1356.4	1346.2	1336.4	1326.7	1317.2	1308.0
115	1404.5	1393.1	1382.1	1371.3	1360.7	1350.4	1340.4	1330.5	1320.9	1311.5	1302.3
120	1398.3	1387.0	1376.0	1365.2	1354.7	1344.5	1334.5	1324.7	1315.1	1305.7	1296.5
125	1392.0	1380.8	1369.8	1359.1	1348.7	1338.5	1328.5	1318.8	1309.2	1299.9	1290.7
130	1385.8	1374.6	1363.7	1353.0	1342.7	1332.5	1322.6	1312.8	1303.4	1294.1	1285.0
135	1379.9	1368.8	1357.9	1347.3	1337.0	1326.9	1317.0	1307.3	1297.8	1288.6	1279.5
140	1374.1	1363.0	1352.2	1341.6	1331.3	1321.2	1311.4	1301.7	1292.3	1283.1	1274.1
145	1368.2	1357.1	1346.4	1335.8	1325.6	1315.5	1305.7	1296.1	1286.8	1277.6	1268.6
150	1362.7	1351.7	1341.0	1330.5	1320.2	1310.3	1300.5	1290.9	1281.6	1272.5	1263.5

TABLE II. Pressure function = $(P_1)^{1.02}$ (Discharge pressure, psia)

	0	10	20	30	40	50	60	70	80	90	100
200	222.36	233.70	245.06	256.43	267.80	279.18	290.58	301.99	313.40	324.82	336.25
300	336.25	347.68	359.13	370.58	382.03	393.50	404.97	416.45	427.93	439.42	450.92
400	450.92	462.41	473.92	485.43	496.96	508.47	520.01	531.53	543.07	554.62	566.16
500	566.16	577.72	589.28	600.84	612.41	623.96	635.55	647.13	658.70	670.29	681.88
600	681.88	693.47	705.07	716.67	728.28	739.90	751.50	763.12	774.73	786.36	798.00
700	798.00	809.62	821.24	832.88	844.52	856.17	867.80	879.47	891.11	902.76	914.43
800	914.43	926.08	937.76	949.40	961.08	972.75	984.42	996.09	1007.8	1019.5	1031.1
900	1031.1	1042.8	1054.5	1066.2	1077.9	1089.6	1101.3	1113.0	1124.7	1136.4	1148.2

TABLE III. Station spacing function = $\left(\frac{I}{L}\right)^{.501}$ L = Miles between stations

	0	1	2	3	4	5	6	7	8	9	10
0	—	1.00000	0.70223	0.57102	0.49312	0.44008	0.40092	0.37061	0.34628	0.32608	0.30903
10	0.30903	0.29436	0.28159	0.27033	0.26029	0.25129	0.24316	0.23575	0.22898	0.22276	0.21701
20	0.21701	0.21166	0.20670	0.20206	0.19772	0.19367	0.18983	0.18620	0.18278	0.179540	0.17646
30	0.17646	0.17352	0.17076	0.16809	0.16555	0.16312	0.16078	0.15855	0.15641	0.15436	0.15239
40	0.15239	0.15048	0.14861	0.14685	0.14513	0.14350	0.14188	0.14034	0.13885	0.13738	0.13600
50	0.13600	0.13460	0.13330	0.13199	0.13073	0.12954	0.12833	0.12719	0.12608	0.12495	0.12390
60	0.12390	0.12287	0.12183	0.12087	0.11989	0.11895	0.11804	0.11712	0.11624	0.11539	0.11453
70	0.11453	0.11371	0.11288	0.11209	0.11134	0.11058	0.10981	0.10909	0.10840	0.10766	0.10701
80	0.10701	0.10631	0.10565	0.10498	0.10436	0.10373	0.10310	0.10251	0.10192	0.10132	0.10077
90	0.10077	0.10016	0.099604	0.099087	0.098523	0.098001	0.097476	0.096950	0.096469	0.095986	0.095499
100	0.095499	0.095017	0.094537	0.094068	0.093607	0.093149	0.092704	0.092257	0.091823	0.091393	0.090964
110	0.090964	0.090551	0.090134	0.089727	0.089323	0.088926	0.088534	0.088152	0.087767	0.087392	0.087018
120	0.087018	0.086651	0.086286	0.085931	0.085576	0.085228	0.084879	0.084540	0.084200	0.083865	0.083539
130	0.083589	0.083211	0.082888	0.082570	0.082255	0.081945	0.081634	0.081334	0.081033	0.080735	0.080436
140	0.080436	0.080149	0.079860	0.079576	0.079292	0.079012	0.078736	0.078461	0.078190	0.077924	0.077657
150	0.077657	0.077395	0.077131	0.076874	0.076622	0.076368	0.076120	0.075872	0.075629	0.075384	0.075145
160	0.075145	0.074907	0.074666	0.074437	0.074201	0.073973	0.073748	0.073523	0.073296	0.073077	0.072855
170	0.072855	0.072641	0.072425	0.072209	0.071998	0.071786	0.071575	0.071369	0.071169	0.070963	0.070760
180	0.070760	0.070559	0.070364	0.070168	0.069971	0.069780	0.069589	0.069397	0.069212	0.069026	0.068838
190	0.068838	0.068652	0.068472	0.068290	0.068108	0.067933	0.067756	0.067580	0.067403	0.067233	0.067063

TABLE V. F_r = Ratio Function $\left(\frac{r^2-1}{r^2}\right)^{0.510}$

r	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10
1.20	0.54621	0.55652	0.56646	0.57598	0.58510	0.59391	0.60235	0.61043	0.61833	0.62589	0.63321
1.30	0.63321	0.64029	0.64714	0.65378	0.66019	0.66647	0.67247	0.67834	0.68402	0.68951	0.69482
1.40	0.69482	0.70008	0.70508	0.71000	0.71479	0.71943	0.72397	0.72840	0.73269	0.73687	0.74095
1.50	0.74095	0.74496	0.74881	0.75265	0.75631	0.75991	0.76342	0.76692	0.77027	0.77354	0.77673
1.60	0.77673	0.77990	0.78294	0.78598	0.78886	0.79174	0.79461	0.79734	0.80000	0.80264	0.80523
1.70	0.80523	0.80780	0.81024	0.81266	0.81508	0.81738	0.81967	0.82194	0.82410	0.82625	0.82838
1.80	0.82838	0.83047	0.83253	0.83449	0.83649	0.83842	0.84029	0.84215	0.84396	0.84575	0.84748
1.90	0.84748	0.84922	0.85094	0.85261	0.85422	0.85588	0.85742	0.85902	0.86054	0.86203	0.86356
2.00	0.86356	0.86495	0.86643	0.86782	0.86922	0.87056	0.87191	0.87326	0.87452	0.87579	0.87706
2.10	0.87706	0.87828	0.87955	0.88071	0.88192	0.88306	0.88422	0.88536	0.88644	0.88755	0.88863

TABLE IV. Pipe diameter function — F_D

OD, in.	Wall thickness, in.	I.D., in.	F_D $(ID)^{2.53}$	OD, in.	Wall thickness, in.	I.D., in.	F_D $(ID)^{2.53}$
2⅜	0.154	2.067	6.2778	16	0.219	15.562	1037.4
3½	0.216	3.068	17.051		0.250	15.500	1026.9
	0.300	2.900	14.786		0.281	15.438	1016.6
4½	0.237	4.026	33.910		0.312	15.375	1006.1
	0.337	3.926	31.819		0.344	15.312	995.71
6⅝	0.250	6.125	98.032		0.375	15.250	985.53
	0.280	6.065	95.622		0.438	15.125	965.23
	0.432	5.761	83.956	18	0.250	17.500	1396.0
8⅝	0.187	8.250	208.27		0.281	17.438	1383.5
	0.203	8.219	206.30		0.312	17.375	1370.9
	0.219	8.187	204.27		0.344	17.312	1358.4
	0.250	8.125	200.38		0.375	17.250	1346.1
	0.277	8.071	197.02		0.409	17.182	1332.7
	0.322	7.981	191.51		0.438	17.125	1321.6
10¾	0.203	10.344	369.12	20	0.250	19.500	1835.6
	0.219	10.312	366.23		0.281	19.438	1820.9
	0.250	10.250	360.69		0.312	19.375	1806.0
	0.279	10.192	355.55		0.344	19.312	1791.2
	0.307	10.136	350.62		0.375	19.250	1776.6
	0.344	10.062	344.18		0.409	19.182	1760.8
	0.365	10.020	340.56		0.438	19.125	1747.6
12¾	0.203	12.344	577.28	22	0.250	21.500	2350.0
	0.219	12.312	573.50		0.281	21.438	2332.9
	0.250	12.250	566.22		0.312	21.375	2315.6
	0.281	12.188	559.00		0.344	21.312	2298.4
	0.312	12.125	551.72		0.375	21.250	2281.4
	0.330	12.090	547.68		0.438	21.125	2247.7
	0.344	12.062	544.49		0.500	21.000	2214.2
	0.375	12.000	537.43	24	0.250	23.500	2943.1
	0.438	11.875	523.39		0.281	23.438	2923.5
14	0.210	13.580	734.90		0.312	23.375	2903.6
	0.219	13.562	732.44		0.344	23.312	2883.9
	0.250	13.500	724.00		0.375	23.250	2864.5
	0.281	13.438	715.63		0.438	23.125	2825.7
	0.312	13.375	706.57		0.500	23.000	2787.2
	0.344	13.312	698.77				
	0.375	13.250	690.56				

$F_{GT} = 1421.57$ ..... Table I
$F_p = 1031.2$ ..... Table II
$F_L = 0.10701$ ..... Table III
$F_D = 3574.8$ ..... Table IV
$F_r = 0.78892$ ..... Table V

$$Q = 1421.57 \times 1031.2 \times 0.10701 \times 3574.8 \times 0.78892 \times 0.92 = \mathbf{407{,}000}\ \text{MCF/Day.}$$

Example No. 2

Find the downstream pressure, P_2

Given:

$P_0 = 14.73$
$T_0 = 60$ F
$P_1 = 1000$ psia
$T_f = 80$ F
$G = 0.600$
$D = 35.250$ in. ID (36 in. OD)
$L = 100$ miles
$Q = 900$ MMCF/Day
$E = 95$ per cent

$$F_r = \frac{Q}{F_{GT} \times F_p \times F_L \times F_D \times E}$$

$F_{GT} = 1450.03$ ..... Table I
$F_p = 1148.2$ ..... Table II
$F_L = 0.09550$ ..... Table III
$F_D = 8209.4$ ..... Table IV

$$F_r = \frac{900{,}000{,}000}{1450.03 \times 1148.2 \times 0.09550 \times 8209.4 \times .95}$$

$F_r = 0.72579$
$r = 1.46$ ..... Table V

$$P_2 = \frac{1000}{1.46} = \mathbf{685}\ \text{psia}$$

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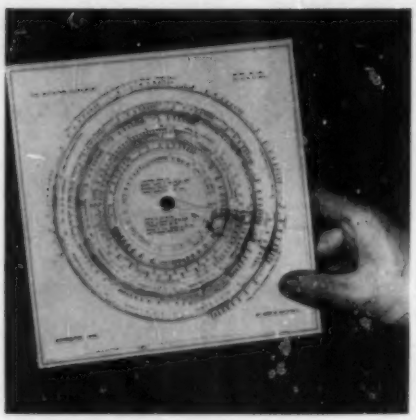

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FPC Publishes Regulations Under Natural Gas Act

The Federal Power Commission has issued a pamphlet edition of its regulations under the Natural Gas Act, including approved forms.

The edition contains subchapters E and G, regulations under the Natural Gas Act, with approved forms, of the FPC, rules and regulations in effect April 1, 1956.

With the publication of the new pamphlet, the Commission's rules and regulations are now available in separate pamphlet editions. The Commission in 1955 issued its Rules of Practice and Procedure, including General Policy and Interpretations (A-48, 30 cents per copy), and its Regulations under the Federal Power Act, with approved forms (A-49, 40 cents per copy), in pamphlet editions.

The FPC's Uniform System of Accounts Prescribed for Public Utilities and Licensees (A-5, 60 cents per copy), and Uniform System of Accounts Prescribed for Natural Gas Companies (A-12, 40 cents per copy), have been available in separate pamphlets for several years.

Copies of the new pamphlet, Regulations under the Natural Gas Act, may be purchased from the Federal Power Commission, Washington 25, D. C., for 35 cents per copy. The order number is FPC A-50.

Transcontinental Gas Sets New Records

Operations of Transcontinental Gas Pipe Line Corporation, Houston, Texas, in the first three months of this year resulted in new high records for gas deliveries, operating revenues and net income, Tom P. Walker, president, told stockholders at their annual meeting recently.

Earnings for the first quarter, he said, were equal to 31 cents per share on the common stock compared with 25 cents per share for the first quarter last year. These earnings are based on 7,060,000 outstanding shares after giving effect to a two-for-one split of the common stock in January of this year.

Walker announced that negotiations had been completed for the sale of $40,000,000 first mortgage pipe line bonds in May and $20,000,000 of debentures in November. Proceeds from the sale of these securities will be used to retire the presently outstanding $60,000,000 bank loan.

All directors of the company were re-elected.

PIPE LINE COMMUNICATION & CONTROL

Microwave System Planning

A graphical approach to simplified point-to-point system planning

Part 4: Propagation Factors

ABOUT PART 4 OF THIS SERIES

In planning a microwave system, it is not necessary to delve deep into classical electromagnetic wave equations. An earthy understanding of the basic mechanics of microwave propagation is essential, however, in planning paths for reliable communication. Part 4 and 5 of this series summarize the fundamentals of microwave propagation and graphically depict their effect on the transmitted signal.

Part 4 outlines the propagation factors which cause transmission to vary from the nominal free-space value. Refraction in the atmosphere, or "beam-bending," is described in terms of effective earth size, which is seen to vary with atmospheric conditions.

Part 5 covers the remaining propagation factors of reflection from earth surface and diffraction around path obstacles. A full-page PATH PLANNING GRAPH depicts the effect of these three major propagation factors. The graph shows the variations in clearance with atmospheric conditions (effective earth size) and the resultant effect on microwave transmission over reflective and non-reflective paths.

The use of air instead of copper as the communication medium has obvious advantages in economy, all-weather reliability, and ease of maintenance. These advantages proven by 17,000 miles of microwave systems in the petroleum industry, justify mastery of the propagation phenomena.

Lee Elmore, *Collins Radio Company*

MICROWAVE transmission differs from conventional radio in several important and unique respects — all of which are due to the high frequencies or short wave-lengths in the microwave bands. These key characteristics of microwave transmission are:

1. *High directivity.*
2. *Large power gains.*
3. *Large bandwidth, or information-carrying capacity.*
4. *Essentially line-of-sight transmission.*

This combination of properties makes microwave almost ideally suited to multi-channel communication by means of low-power, economical, unattended relay stations.

Directivity

At microwave frequencies, wavelengths are very short compared to antenna size. This permits ready focusing of microwave energy into narrow beams. This focusing may be accomplished by means of a parabolic dish, horn, lens, helix or array. Parabolic antennas are widely used in microwave communication. The principle is analogous to focusing of light rays in a searchlight:

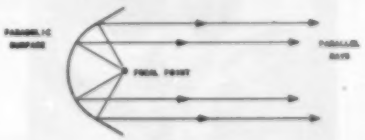

FIG 1

The parabolic surface is so shaped that all rays illuminating the parabola from the focal point will be reflected in parallel lines. The resultant beam consists of a narrow conical major lobe and a number of minor lobes as shown in the radiation pattern below:

The beamwidth as measured at the half-power points (3 db below maximum radiation at 0 deg) is approximately

$$\Theta = 2.26\frac{\lambda}{D}$$

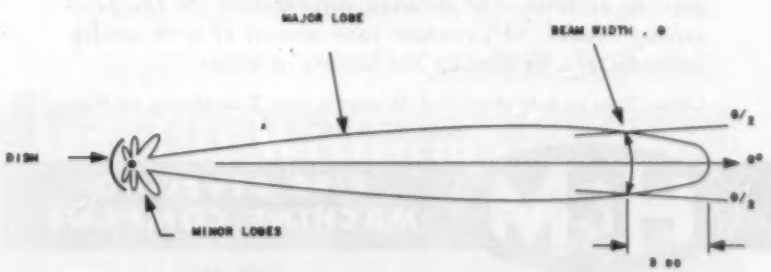

FIG. 2

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Where λ is the wavelength in cm and D is the diameter of the dish in feet. The beamwidth of a 6-ft paraboloid is seen to be 1.7 deg at 6700 mc ($\lambda = 4.5$ cm) and 5.8 deg at 2000 mc ($\lambda = 15$ cm).

The highly directive beams permit reallocation of transmitter frequencies for different sites and path bearings in a given area. The line-of-sight propagation permits reallocation of the entire microwave spectrum beyond the horizon. Thus, the number of microwave stations is limited only by geography, thereby permitting multiple reuse of frequency spectrum — a limited natural resource — without interference.

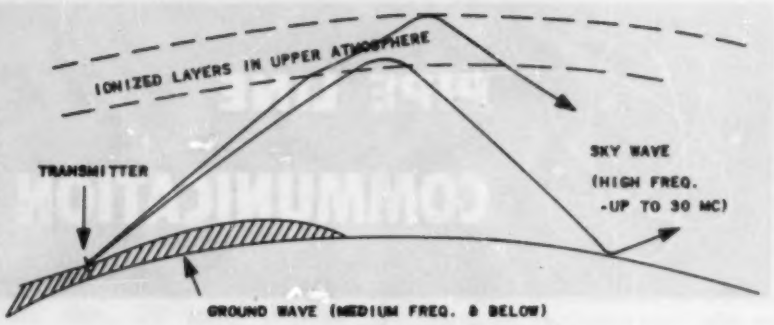

FIG. 3. Radio Transmission Below 30 mc.

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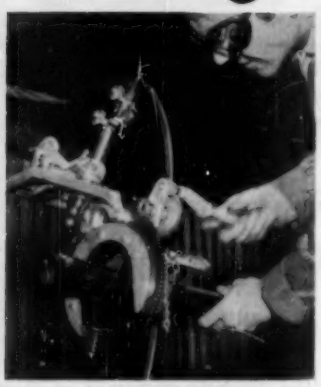

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The geographical convergance of microwave systems in cities like Houston and along certain routes, such as "microwave alley" across Pennsylvania, already necessitates careful planning to avoid interference. Information concerning frequencies, sites, and radiation patterns of existing or planned microwave systems can be obtained from the Operational Fixed Microwave Council, which serves as a clearinghouse of data to assure efficient and non-interfering usage of the operational fixed microwave bands.

Power Gain

The concentration of radiated energy into a narrow beam aimed at the receiving point provides a large effective power gain, compared with the same amount of power radiated in all directions by an isotropic antenna.

The gain of a parabolic antenna in db is

$$G = 20 \log F + 20 \log D - 52.5$$

Where F is frequency in megacycles and D is dish diameter in feet.

With a 6-ft dish, the gain at 6700 mc is seen to be 39.6 db, which is an effective power gain of 9100 per dish. The same size dish at 2000 mc provides a gain of 27.5 db, which is an effective power gain of 560 per dish.

This large power gain is "built into" the dish and, therefore, much cheaper to provide *and maintain* than generated power from transmitter tubes.

Radio Transmission

The simplicity of microwave transmission is best appreciated by comparison with lower frequency radio transmission.

At the *medium frequencies* (300 kc to 3 mc) and below, as typified by the broadcast band, the predominant radiated energy is the *ground wave*. The tall towers used as antennas are a fraction of a wavelength, and earth is an

integral part of the antenna system. Transmission is dependent upon the electrical constants of the earth as well as upon varying atmospheric attenuation.

At the *high frequencies* (3 mc to 30 mc), as typified by long distance communication systems, the predominant energy is in the *sky wave*. Energy radiated above the ground surface will be refracted by the ionized layers in the upper atmosphere, causing these signals to return to earth at great distances from the transmitter. The varying height and density of these ionized layers causes the "skip" distance and maximum usable frequency to vary with daily, seasonal, and sunspot cycles.

At VHF (30 mc to 300 mc) and above, radio transmission is on the basis of essentially line-of-sight propagation analogous to radiation of light waves. VHF and microwave follow the same propagation laws, but VHF is limited in directivity and power gains and subject to interference. VHF is used for short-distance communication, such as mobile radio, air-ground coverage, and commercial television.

At microwave frequencies (1000 mc and above), the antenna is physically independent of ground, and the frequency is too high to be refracted back to earth by the ionosphere. Consequently, the ground wave and sky wave are non-existant. Microwave transmission is on the basis of the *space wave*, which is propagated directly between antennas through the traposphere, or lower atmosphere. Propagation is essentially *straight-line*, but is affected by the presence of atmosphere and terrain as summarized in this article.

Free-Space or No-Fade Propagation

In planning microwave propagation paths, it is convenient to calculate signals on the basis of free-space transmission. Free-space transmission occurs when the medium between the antennas is either a vacuum or a uniform atmosphere, and when the terrain effects are non-existant. Under such conditions, the microwave beam follows a straight line and the signal at the receiver is equal to

Transmitter power $+ 2G - \alpha \pm Z$

Where G is the dish gain, α is the space loss, and Z = antenna component gain or loss (coax lines, duplexers and reflectors), with all terms in db.

The space loss, or free-space attenuation in db, is a constant dependent solely upon the operating frequency and path length as follows:

$$\alpha = 37 + 20 \log F + 20 \log d$$

Where F is in megacycles and d is in miles. Under free-space conditions,

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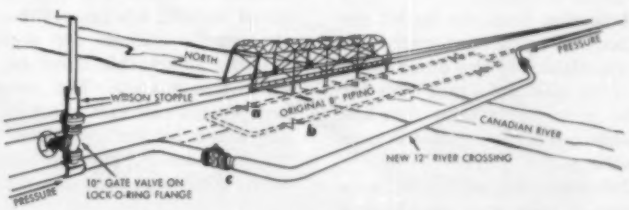

② TAP WAS MADE WITH WmSON-HILLCO MODEL 660 TAPPING MACHINE

③ WmSON STOPPLE REPLACED TAPPING MACHINE ON CLOSED VALVE

④ LINE WAS PLUGGED ISOLATING SECTION BETWEEN STOPPLE AND VALVES a. & b. (CITY LOOP SYSTEM MAINTAINED SERVICE TO RIVER FROM EACH SIDE.)

⑤ ISOLATED SECTION WAS THEN CUT AND NEW 12" CROSSING TIED INTO 10" LINE

⑥ FOR REMOVAL OF VALVE, LOCK-O-RING PLUG WAS INSTALLED IN L-O-R FLANGE WITH TAPPING MACHINE

⑦ TAPPING MACHINE AND GATE VALVE WERE REMOVED AND BLIND FLANGE INSTALLED

THIS ENTIRE OPERATION WAS THEN REPEATED ON THE OPPOSITE SIDE OF THE RIVER

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therefore, microwave transmission values are readily calculated and constant.

The actual transmission over a path is identical to the free-space or nominal calculation under no-fade conditions, which occur most of the time over well-planned paths. The free-space values are graphically depicted in Part 5 as a function of path length, equipment parameters, frequency band, and antenna size.

In the following columns, we will consider the normal and predictable extremes of propagation due to atmospheric and terrain factors as an aid in planning path layouts and anticipating propagation fades over various paths.

Fade margins are incorporated in a system to assure reliable communication under the anticipated fade conditions. Later in the series, we will correlate fade margins with percent propagation reliability and voice circuit quality over actual microwave links.

Propagation Factors

The atmospheric and terrain factors that cause microwave transmission to vary from the free-space values or to veer from the straight-line path are summarized below:

1. **Refraction** in the atmosphere causes bending of the microwave beam from a straight-line path. The result is a normal variation in actual path clearance with respect to first Fresnel Zone radius. Ducting, or trapping of the microwave beam in a particular atmospheric layer, is a special rare case of refraction.
2. **Reflection** from the earth's surface may cause reinforcement or cancellation of the direct signal by the reflected signal. This factor is minor in most over-land paths but becomes acute in over-water paths.
3. **Diffraction** around earth curvature or path obstacles produces a reduced signal strength in the "shadow" region.
4. **Absorption** due to attenuation or scattering of microwave energy by heavy raindrops or other atmospheric particles causes a minor loss in the frequency bands considered.

The nature and extent of these propagation factors are covered in the following pages in terms of their effect on received signal strength. The major factors (1, 2 and 3 above) are directly related in the *Path Planning Graph* to depict the resultant variations in received signal with respect to free-space or no-fade transmission.

Refraction

A slight bending of the microwave beam from its straight-line path is the rule rather than the exception. If the dielectric constant of the atmosphere were uniform throughout a path, the propagation would follow a straight line. The dielectric constant is a function of atmospheric pressure, temperature, and humidity. This "constant," therefore, changes with height and weather conditions.

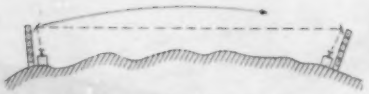


FIG. 4. Microwave transmission over land, showing normal refraction, or slight downward bending of microwave beam.

FIG. 5. Microwave transmission over water, or smooth surface, showing reflected signal and direct signal producing multipath interference.

Normally, the dielectric constant decreases with height, resulting in a slight downward bending of the beam. Since microwave antennas are aligned for maximum signal over a link, this downward bending results in a mid-path clearance which is somewhat greater than planned on a straight-line basis. Fig. 4 illustrates this normal refraction. The curved ray is at right angles to the radiated wave fronts.

As the atmospheric medium varies, the bending will vary from a greater amount of downward bending to an actual upward bending. Although the atmospheric changes are slight, they have an appreciable effect on microwave transmission. The amount of bending and resultant effect on propagation can be predicted from the refraction index and graphically analyzed by the effective earth radius concept.

Refractive Index

The amount of bending depends upon the *refractive index* of the atmosphere, or more important, upon the *gradient* of refractive index with height.

The velocity of radio waves through a medium is

$$\text{velocity} = \frac{\text{speed of light}}{\text{refractive index}}$$

The refractive index of a vacuum is 1. In the atmosphere, the refractive index is approximately 1.0003 and generally decreases minutely with height. The upper portions of the wave fronts move with higher velocity than the lower portions, causing the normally-expected slight downward bending of the microwave beam.

The refractive index of moist air can be determined from the following empirical formula, which is based on numerous experiments correlating propagation data with meteorological measurements:

$$(n - 1) \times 10^6 = \frac{79}{T}\left(p - e + \frac{4800e}{T}\right)$$

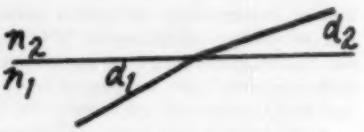
where:

n = index of refraction
p = barometer pressure in millibars
e = partial pressure of water vapor in millibars and
T = absolute temperature.

In the moist standard atmosphere specified by NACA for temperate zones, the change in refraction index with height above sea level is

$$\frac{dn}{dh} = -.039 \times 10^6 \text{ units per meter}$$

The extent of bending which occurs at the boundary of two media having different refraction indices as shown below is:



$$n_1 \cos \alpha_1 = n_2 \cos \alpha_2$$

Where n represents refractive index of the two layers, and α_1 and α_2 are the angles between the rays and the boundary.

Since the refractive index is a continuous function of height in the atmosphere, the abrupt change of direction at a boundary (above) becomes a gradual curvature of the ray. The above equation then becomes

$$n \cos \alpha = n_0 \cos \alpha_0$$

Where n and α are continuous functions of height and the subscript zero designates a reference level, which is plane earth in the above case. For a spherical earth and curved atmospheric layers, this becomes

$$nr \cos \alpha = n_0 a \cos \alpha_0$$

where r is the radius from earth center to the atmospheric level considered and a is earth radius.

Since the height above earth is h = r — a, we can set r = a (1 + h/a) and note that h/a is negligible. With a linear gradient of refractive index,

$$n = n_0 + \frac{dn}{dh} \times h$$

Substituting in the above formula for nr cos α, and deleting negligible quantities, we get

$$\left[1 + \left(1/a + \frac{dn}{dh}\right) h\right] \cos \alpha = \cos \alpha_0$$

This equation shows that a linear gradient of refractive index has the same effect on refraction as the earth's curvature, 1/a. By introducing an effective earth radius, ka, it is possible to

eliminate the refraction term and treat the atmosphere as if it were homogeneous. We then have

$$\frac{1}{a} + \frac{dn}{dh} = \frac{1}{ka}$$

and

$$k = \frac{1}{1 + a\frac{dn}{dh}}$$

For the standard moist atmosphere in which

$$\frac{dn}{dh} = -0.039 \times 10^{6} \text{ per meter},$$

k is found to be 4/3 earth radius.

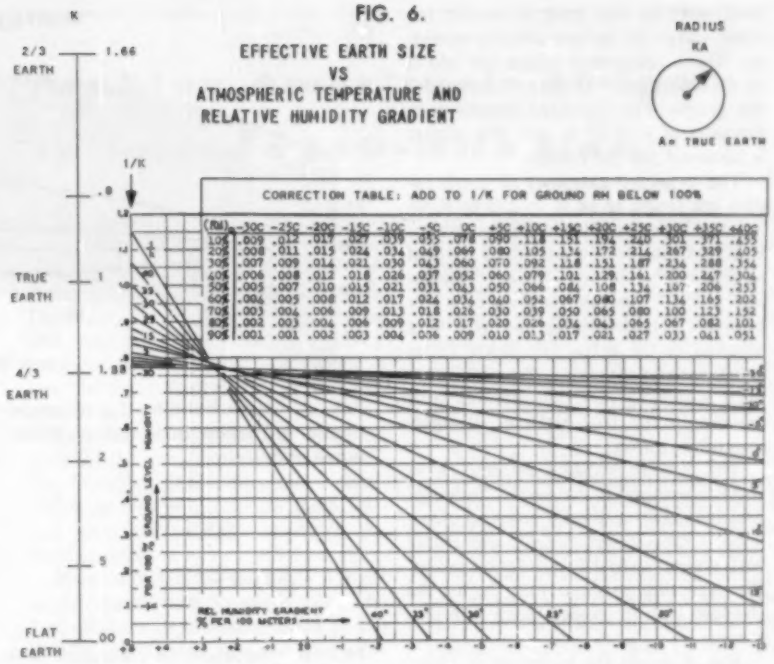
Effective Earth Size

This effective earth curvature of 4/3 earth is readily used for considering straight-line propagation under "standard" atmospheric conditions. This average value applies only to the middle geographical latitudes. In arctic climates, k is somewhat smaller (between 4/3 and 6/5). In tropical climates, k is somewhat larger (between 4/3 and 3/2). In both temperate and tropical climates, k is strongly affected by the humidity gradient in the lower atmosphere.

As shown earlier, the refractive index can be directly determined from the atmospheric pressure, temperature and humidity. With a linear gradient of refractive index in the lower atmosphere in which microwave propagation takes place, k can be determined directly for any combination of atmospheric conductions. Fig. 6 shows 1/k as a function of relative humidity gradient for a series of surface temperatures between — 30 C and + 40 C.

The graph is plotted for a relative humidity of 100 per cent at ground

FIG. 6.



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level, with an inset table to correct for other values of surface relative humidity. These correction values are added to the values of 1/k determined from the graph. The standard temperature gradient of —0.65 C per 100 meters is assumed for the curves.

The expected extremes of earth radius are found to be k = 2/3 to K = ∞, the latter corresponding to downward bending with a curvature parallel to true earth curvature (earth "flattening"). Fig. 7 shows the path of a ray between a transmitting and receiving antenna as the refractive index varies between these extremes. The path clearance is seen to vary considerably with respect to the true-earth or straight-line propagation.

The upward bending extreme (k = 2/3) corresponds to earth "bulging" and results in a greatly reduced clearance. Unless tower heights are ample with respect to first Fresnel zone radius, the receiving antenna may be in the shadow region under such circumstances.

Fig. 8 shows the variation in clearance over a typical 30 mile path under various propagation conditions. There is little difference in the magnitude of bending or per cent of time at k = 1 and k = 4/3. The two extremes of bending, at which the clearance varies greatly, occur for only a small portion of the time.

Profile Chart Curvature

The refractive index is the square root of the dielectric constant. Physical studies have shown that the dielectric constant of an insulator such as air varies with frequency as shown in Fig. 9, which depicts the total electromagnetic spectrum.

The dielectric constant (and refractive index) is seen to be constant throughout the microwave frequency bands. **The amount of bending is, therefore, identical at all four microwave bands, 960 to 6700 mc.**

Profile charts can be constructed on the basis of 4/3 earth curvature, true earth curvature, or rectangular coordinates (flat earth with all elevation data corrected for any effective curvature). The rectangular profile method has been used in planning major common carrier routes for both over-land and over-water paths. Such paths are analyzed for propagation conditions between the extremes of flat earth and 2/3 earth radius to assure reliable transmission at all times.

Use of 4/3 earth profile is satisfactory for showing the average condition over a VHF, microwave or radar path.

True earth profile is generally preferable in planning point-to-point microwave paths for conservative practice. For a given Fresnel clearance (such as 0.6 R), the use of true earth profiles provides a higher tower, thereby compensating for a more severe upward bending than in the case of 4/3 earth.

The *Path Planning Graph* in Part 5 permits combining the conven-

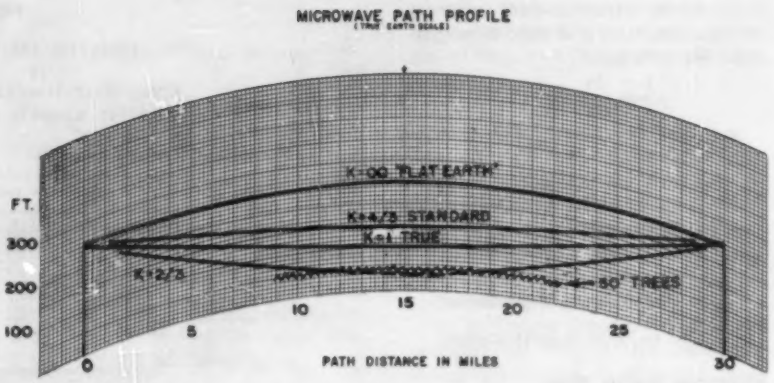

FIG. 7. Beam bending due to atmospheric refraction over typical microwave path.

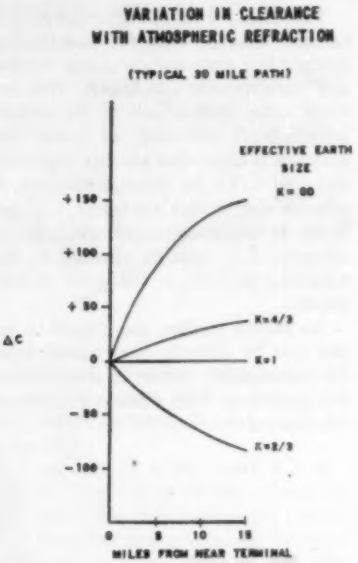

FIG. 8. Variation in clearance with bending.

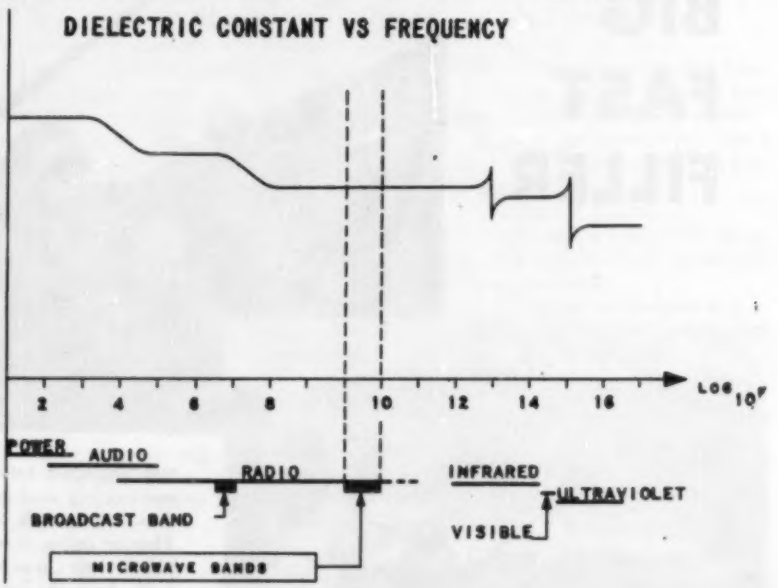

FIG. 9. Dielectric constant of atmosphere shows no change in refraction throughout microwave frequency bands. (Vertical scale exaggerated.)

ience of true earth profiles with the analytical methods of the rectangular profile, thereby permitting rapid and accurate determination of microwave transmission under varying propagation conditions.

Ducting

Ducting is a special case of refraction in which the microwave energy is trapped in a particular atmospheric layer.

Surface ducts, in which the microwave energy is trapped just above the surface, cause the energy to follow earth curvature. Such ducts are fairly common over the surface of the sea. Elevated ducts, in which the microwave energy is trapped at a particular stratified atmospheric level, are quite rare.

Ducting is caused by a non-linear variation of refractive index with height as shown in Fig. 10. Ducting occurs in the inversion layers as illustrated.

When both the transmitting and receiving antennas are in the ducted

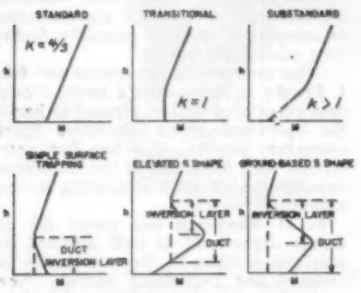

FIG. 10. Modified refractive index curves.

layer, the waves cannot fan out and will be transmitted with a plane rather than a spherical wave front. The received signal will therefore be greater than the free space value.

When one of the antennas is outside the duct by an appreciable amount, the received signal will be negligible, resulting in a complete fade. Fortunately, this is a rare occurrence.

Sites should be selected to avoid paths which exhibit a tendency toward inversion layers. Such layers are found where the moisture content or temperature varies abruptly in a stratified atmosphere. A turbulent or uniform atmosphere is desired to produce a heterogeneous medium and avoid ducting.

The phenomenon of ducting has been studied extensively in radar work, and considerable information has been published to correlate meteorological data with ducting.

Ducts which result in microwave outage are almost non-existant over well-planned over-land paths. ★ ★ ★

Arabian American's Budget To Include 140-Mile Line

THE Arabian American Oil Company has announced in its annual report of operations a capital expenditures budget of $80,000,000 for 1956. This sum, Chairman of the Board F. A. Davies and President R. L. Keyes declared, provides for "a greater investment in new facilities than in any of the past several years."

The capital expenditures program calls for the construction of new facilities, including a gas-oil separator plant, a bulk plant, a pump station and a 140-mile pipe line to Ras Tanura on the Persian Gulf.

The new Safaniya facilities will place in production the Safaniya field, the first offshore deposit developed in the Persian Gulf, and increase the producing capacity of the 140-mile-long Ghawar Field, one of the world's largest oil reservoirs.

The expansion plans for the Ghawar Field involve the drilling of new wells in the 'Uthmaniyah' area and the building of a new permanent community named 'Udhailiyah.'

According to the report, Aramco's oil production rose to a record of 965,041 bbl a day in Saudi Arabia during 1955. At the end of the year, Aramco's reserves were estimated at 30 to 35 billion barrels.

Aramco is owned jointly by the Standard Oil Company of California, The Texas Company, Standard Oil Company (New Jersey) and Socony Mobil Oil Company. Socony owns a 10 per cent share and the other three companies 30 per cent each.

Other major plans for 1956 call for expanded educational, health, housing and cafeteria facilities, a new administration building in Dhahran, a 15,000-bbl-a-day unit at the Ras Tanura refinery to remove sulfur compounds from diesel oil, and the extension of Ras Tanura's south pier so that it can handle supertankers.

The Aramco report noted that the record 1955 production exceeded the 1954 level by 12,041 bbl a day. A monthly record also was set with the production of 1,041,098 bbl a day during November. At the end of the year, 154 wells, more than in any previous year, were producing crude oil.

The total production for 1955 amounted to 352,239,912 bbl. This level, Chairman Davies and President Keyes asserted, "was a better achievement than was anticipated a year ago, when it appeared that the return of Iranian oil to world markets in increasing amounts might result in a decline in Aramco's production for 1955. There continued to be a substantial surplus of producing capactiy in the Middle East, and competition for world oil markets was increasingly keen."

The Aramco report showed a decline in demand for petroleum products from its Ras Tanura refinery. The refinery processed 74,171,745 bbl of crude oil in 1955, or 5,672,851 bbl less than in 1954. The 1955 average was 203,210 bbl a day. A fluid hydroformer, constructed at a cost of $13,000,000, was placed in service at Ras Tanura. The first such catalytic reforming unit to be built in the Middle East, it enabled the refinery to meet demands for higher quality gasoline. A total of 2,096,450 bbl of refined products, more than ever before, was distributed by Aramco within Saudi Arabia.

The 120-page report, of which 95,000 copies were printed in both English and Arabic, emphasized Aramco's contributions during 1955 to the well-being of its 21,073 employees and to the people of Saudi Arabia. A total of 11,349 individual wage increases was granted to Saudi employees for better job performance and through promotions. The average annual income of Saudi employees was more than double the 1950 rate. In addition, the company spent an amount equal to wages and salaries to provide educational, medical, housing and other benefits for its Saudi employees.

New "opportunity schools" for training Saudi employees were completed last year at Dhahran and Abqaiq, at a cost of $716,580. A third such school was scheduled for construction in Ras Tanura. Six other schools, built by Aramco to assist in the education of sons of Saudi employees, were operating and four more were begun or planned. The cost of the ten schools, which became integral parts of the Saudi government school system, was estimated at $1,270,000.

Approximately $2,500,000 was spent in 1955 on expansion of the company's modern hospital-clinic at Dhahran and on construction of a new hospital-clinic at Abqaiq.

PIPE LINE PERSONALS

William H. Sloan has been made superintendent of natural gas liquids in Cities Service Oil Company's supply and distribution division. He joined Cities Service in 1947 and most recently has been serving as assistant to the manager of the company's pipe line transportation division.

George A. Patterson has been promoted to assistant superintendent of the pipe lines department, The Ohio Fuel Gas Company, Columbus. Patterson has been with the company 22 years, the last 14 as an engineer in the pipe line department.

James L. Hopkins has been named superintendent of the western division of the pipe lines department. He has been associated with Ohio Fuel and its parent company, the Columbia Gas System, for 26 years, and has been supervisor of the corrosion department since 1953.

W. Gould Bethel has been promoted to West Ohio district foreman and will have his headquarters in Springfield. Recently he has been a general inspector in the Columbus general offices.

William H. Gretter has been made division clerk in the southern division of the compressor department. He replaces **Russell Ashbaugh,** who has been transferred to the plant accounting department in Columbus.

V. W. Tipton of Shell Pipe Line Corporation has been named the petroleum industry's safest fleet truck driver in Texas, by the Texas Safety Association. He has driven more than 950,000 accident-free miles during his 23 years with Shell, now averaging about 40,000 miles a year.

Joe E. McGeath has been elected to the board of directors of Magnolia Pipe Line Company. **R. L. Taylor,** assistant to the manager of Magnolia Pipe Line Company, was named as assistant secretary. McGeath joined Magnolia in 1923 as a member of a connection gang, rising to general superintendent in 1954. R. L. Taylor joined Magnolia as a clerk in the pipe line accounting department in 1923.

Other company advancements are: **Douglas E. White,** superintendent of maintenance, has been named assistant chief engineer. With Magnolia since 1928, he had served in his former position since 1947. Succeeding White will be **Charles R. McKenney** who has been assistant superintendent of maintenance. He began his career with Magnolia in 1934, as an oiler. His replacement will be **Doyle F. Maples,** with Magnolia since 1937, formerly general maintenance foreman for the company.

J. E. McGeath

D. E. White

James E. Grubbs has been appointed assistant superintendent of dispatching for Texas Gas Transmission Corporation. He has been division superintendent at Guthrie, Louisiana, and Memphis, Tennessee since 1951.

Volney H. Kyle, Jr., has resigned as vice president and manager of operations of the Michigan-Wisconsin Pipe Line Company to engage in consulting engineering activities in Grosse Pointe, Michigan.

W. W. Lowe, vice-president and director of Cities Service Petroleum, Inc., has been elected president of the Wolverine Pipe Line Company, succeeding **C. S. Gentry,** who is retiring. Lowe is also a director of Cities Service Refining Corporation and of Cities Service Research and Development Company. He has been associated with Cities Service for more than 40 years.

A. L. Roberts, general superintendent of operations for Texas Gas Transmission Corporation, has been elected a vice president by the board of directors. He will continue in his present position, which he has held since 1949, and will assist in directing operations and maintenance of the pipeline system.

A. L. Roberts

M. E. Foster has resigned as president of the Phillips Pipe Line Company and plans to retire in June. In the oil business since 1919, and with Phillips more than 32 years, he is taking early retirement to open an office in Bartlesville, Oklahoma as a consultant in the supply and transportation field.

D. M. McBride was elected president of Phillips, succeeding Foster and **Myron O. Johnson** was elected vice president and general manager. All other officers and directors were re-elected.

Retirement of **Harry L. Masser,** executive vice president of the Southern California Gas Company, after nearly 40 years service, and election of **R. I. Snyder** as vice president has been announced. Snyder, formerly manager of the distribution department for the utility, was named assistant vice president last September to serve as a general assistant to Masser. He will direct customer service and distribution department activities.

C. R. McKenney

D. F. Maples

W. H. Davidson

F. B. Haverfield

Walter H. Davidson has been named vice president for operations of Transcontinental Gas Pipe Line Corporation. Prior to this election he had been vice president and general superintendent. Davidson came to Transco as general superintendent in 1950, following an association with Fish Constructors.

F. B. (Duck) Haverfield, Transco's superintendent of compressor stations since 1950, has been named general superintendent to succeed Davidson. Previously Haverfield had been with Continental Oil Company for 24 years. **Howard L. Cline,** with Transco since 1951, and formerly assistant superintendent, was named to succeed Haverfield.

Hugh M. Pendley has been named purchasing agent for Northern Natural Gas Company to fill the vacancy left by the recent death of **C. Frank Martin.** Pendley has 20 years' service with Northern, the last eight as assistant superintendent of compressor stations primarily dealing with plant construction.

Other company appointments are: **John J. Franks** as director of a newly created data processing section, created to handle the operation of an electronic digital computer. Franks, who has five years' service with Northern in the accounting department, has been accounting systems supervisor.

F. D. Stockman has joined the gas supply department as staff assistant and chief of services of the company's gas reserves and availability section. Previously he was with Phillips Petroleum Company.

Jack W. Seaman has been appointed assistant superintendent of compressor stations, replacing Hugh M. Pendley. Seaman has 18 years experience with the company in the compressor department, and formerly was staff assistant.

Jack Leveritt has joined the company as a field representative for the gas supply department. He will also serve in a similar capacity for Permian Basin Pipeline Company, subsidiary of Northern and will headquarter from the Midland, Texas, office of Northern Natural Gas Producing Company, also a subsidiary of Northern. For the past four years he has been with Witco Oil and Gas Company of Amarillo.

A. E. Payne has been named West Texas division superintendent by Humble Pipe Line Company with headquarters in Midland. He has been East Texas division superintendent at Longview. **Hickman E. Hensley,** assistant superintendent at Midland, becomes East Texas division superintendent. **Edgar R. Neath,** district superintendent at Longview, has been named assistant division superintendent at Midland.

C. A. Callahan has been appointed vice president of Majestic Contractors, Ltd., Canada. His headquarters will be in Edmonton, Alberta, and will be in charge of the company's operations in eastern Toronto.

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Tomorrow's Tools—Today!®

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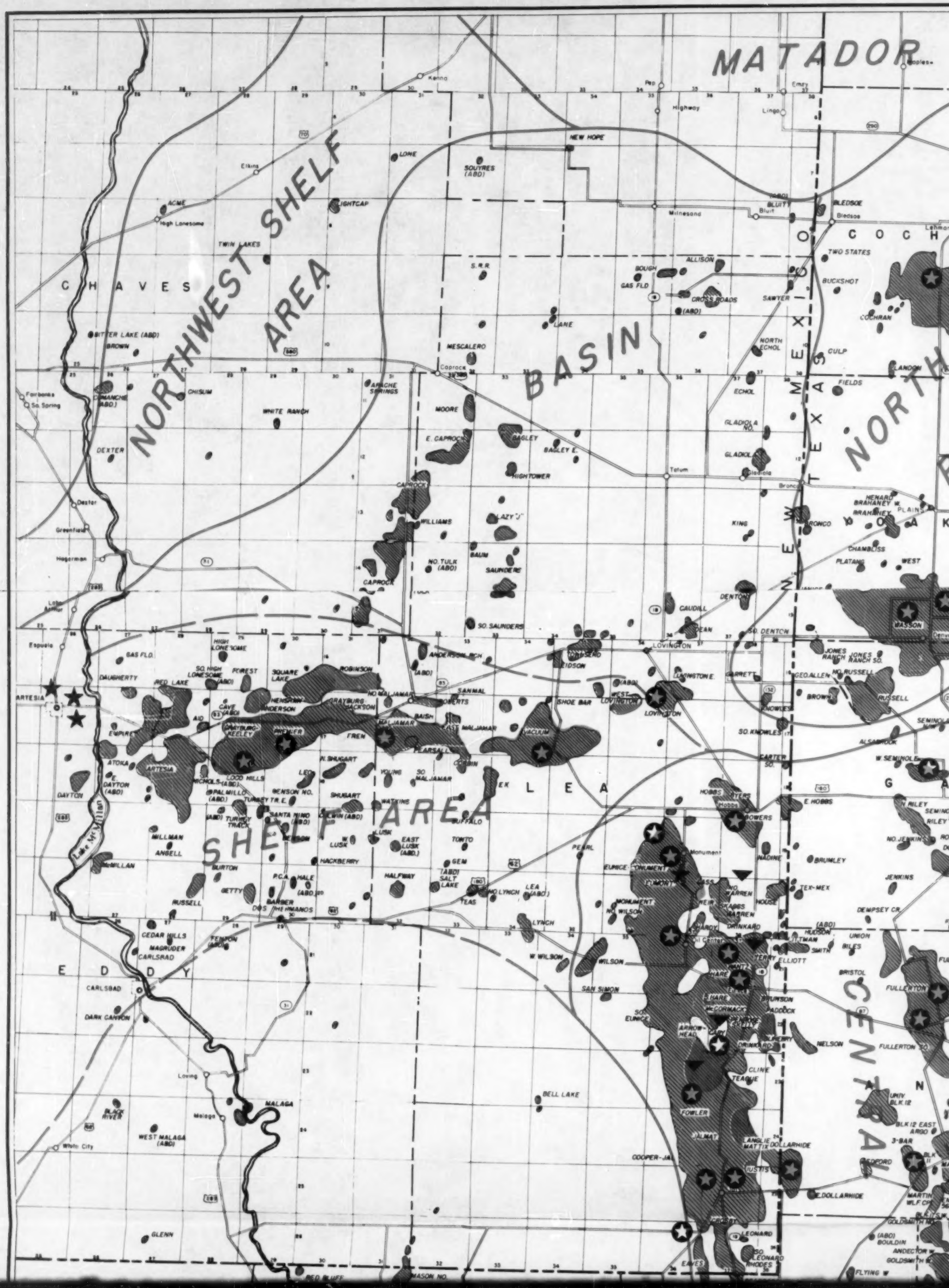
Los Angeles • Houston • Oklahoma City • Lane-Wells Canadian Co. in Canada • Petro-Tech Service Co. in Venezuela

General Offices, Export Office and Plant • 5610 So. Soto St. • Los Angeles 58, California

What about the bits for this location?

This is wildcat territory! But you know... *from long experience*... that Hughes bits of the right sizes, types and design will be ready for delivery before you spud in.

The same is true of the other fifty thousand or more rotary wells to be drilled during the next twelve months. By working closely with the industry the Hughes organization determines, *accurately and far ahead of time,* the bit requirements for each drilling area... and the wildcats, too!


MATADOR
NORTHWEST SHELF AREA
BASIN
CHAVES
EDDY
LEA
NORTH CENTRAL
NEW MEXICO
SHELF AREA
Kenna
Pep
Emory
Highway
Lingo
NEW HOPE
LONE
SOUYRES (ABD)
Elkins
ACME
High Lonesome
LIGHTCAP
TWIN LAKES
BLUITT
Bluitt
Milnesand
BLEDSOE
Bledsoe
TWO STATES
ALLISON
BOUGH GAS FLD
CROSS ROADS (ABD)
SAWYER
BUCKSHOT
COCHRAN
BITTER LAKE (ABD)
BROWN
LANE
MESCALERO
Caprock
NORTH ECHOL
CULP
FIELDS
LANOOM
Forbens
So. Spring
COMANCHE (ABD)
CHISUM
APACHE SPRINGS
WHITE RANCH
MOORE
E. CAPROCK
BAGLEY
BAGLEY E.
ECHOL
GLADIOLA NO.
GLADIOLA
DEXTER
HIGHTOWER
Tatum
Gladiola
Dexter
Greenfield
CAPROCK
WILLIAMS
LAZY "J"
KING
BRONCO
HENARD
BRAHANEY W.
BRAHANEY
PLAINS
Hagerman
NO. TULK (ABD)
BAUM
SAUNDERS
CHAMBLISS
PLATAINS
WEST
CAPROCK
DENTON
CAUDILL
SO. SAUNDERS
SO. DENTON
MASSON
Espuela
GAS FLD.
SO. HIGH LONESOME
HIGH LONESOME
ANDERSON-RICH (ABD)
LOVINGTON
JONES RANCH
JONES RANCH SO.
DAUGHERTY
RED LAKE
FOREST
SQUARE LAKE
ROBINSON
HENSHAW-ANDERSON
GRAYBURG-JACKSON
NO. MALJAMAR
SANMAL
ROBERTS
SHOE BAR
LOVINGTON
LOVINGTON E.
GEO. ALLEN
MC. RUSSELL
BROWN
RUSSELL
ARTESIA
CAVE (ABD)
AID
EMPIRE
GRAYBURG-MORROW
MALJAMAR
EAST MALJAMAR
MACUM
FREN
PEARSALL
KNOWLES
SO. KNOWLES
ATOKA
ARTESIA
W. SHUGART
LEO
YOUNG
SO. MALJAMAR
CORBIN
CARTER SO.
W. SEMINOLE
E. DAYTON (ABD)
DAYTON
NICHOLS (ABD)
LODD HILLS
OPAL HILLS (ABD)
BENSON NO.
SHUGART
WATKINS
HOBBS
HOBBS SO.
E. HOBBS
N. MILEY
SEMINOLE
RILEY
Lake McMillan
SANTA NINO (ABD)
TURKEY TRACK
TURKEY TR. E.
CROSSLIN (ABD)
BUFFALO
MILLMAN
ANGELL
W. LUSK
LUSK
EAST LUSK (ABD.)
TONTO
PEARL
BOWERS
NO. JENKINS
McMILLAN
HACKBERRY
GEM
ABD SALT LAKE
EUNICE
MONUMENT
BRUMLEY
BURTON
HALFWAY
TEAS
NO. LYNCH
LEA (ABD)
TEX-MEX
JENKINS
GETTY
P.G.A.
HALE (ABD.)
BARBER
DOS HERMANOS
NO. WILSON
WARREN
SHARES WARREN
DEMPSEY CR.
RUSSELL
LYNCH
(ABD)
HUDSON
UNION
CEDAR HILLS
MAGRUDER
CARLSBAD
PENROSE (ABD)
W. WILSON
WILSON
SMITH
BILES
TERRY
ELLIOTT
BRISTOL
FULLERTON
CARLSBAD
SAN SIMON
SO. EUNICE
MC. CORMACK
ARKANSAS JUNCTION
ADDOCK
DARK CANYON
NELSON
FULLERTON SO.
CLINE
TEAGUE
Loving
BELL LAKE
MALAGA
FOWLER
UNIV. BLK. 12
BLACK RIVER
Malaga
BLK 12 EAST ARGO
WEST MALAGA (ABD)
White City
PALMAT
LANGLIE MATTIX
DOLLARHIDE
3-BAR
COOPER-JAL
JUSTIS
E. DOLLARHIDE
MARTIN WLF. CRK.
GLENN
LEONARD
SO. LEONARD
RHODES
(ABD) BOULDIN
ANDECTON
GOLDSMITH
EAVES
RED BLUFF
MASON NO.
FLYING W

UPLIFT

AREA

PLATFORM

MIDLAND BASIN

HARTLEY

OLDHAM

DEAF SMITH

RANDALL

CASTRO

PARMER

BAILEY

LAMB

HALE

FLOYD

CROSBY

DICKENS

KING

KNOX

HASKELL

THROCKMORTON

STONEWALL

KENT

GARZA

LYNN

TERRY

YOAKUM

GAINES

DAWSON

BORDEN

SCURRY

FISHER

MITCHELL

HOWARD

MARTIN

ANDREWS

ECTOR

MIDLAND

UPTON

REAGAN

IRION

TOM GREEN

CONCHO

RUNNELS

COKE

COLEMAN

BROWN

CALLAHAN

JONES

SHACKELFORD

STEPHENS

YOUNG

ARCHER

BAYLOR

WICHITA

CLAY

MONTAGUE

COOKE

GRAYSON

FANNIN

LAMAR

RED RIVER

BOWIE

CASS

MORRIS

TITUS

CAMP

UPSHUR

GREGG

HARRISON

PANOLA

SHELBY

SABINE

NACOGDOCHES

ANGELINA

TYLER

JASPER

NEWTON

ORANGE

HARDIN

JEFFERSON

CHAMBERS

LIBERTY

GALVESTON

BRAZORIA

MATAGORDA

WHARTON

JACKSON

VICTORIA

CALHOUN

REFUGIO

ARANSAS

SAN PATRICIO

NUECES

KLEBERG

KENEDY

WILLACY

CAMERON

HIDALGO

STARR

ZAPATA

WEBB

LA SALLE

MCMULLEN

LIVE OAK

BEE

GOLIAD

KARNES

WILSON

ATASCOSA

FRIO

MAVERICK

DIMMIT

ZAVALA

UVALDE

MEDINA

BANDERA

KERR

GILLESPIE

KIMBLE

MASON

LLANO

BURNET

WILLIAMSON

BELL

CORYELL

HAMILTON

MILLS

SAN SABA

MCCULLOCH

MENARD

KIMBLE

SUTTON

EDWARDS

REAL

KINNEY

VAL VERDE

TERRELL

PECOS

CROCKETT

SUTTON

SCHLEICHER

MENARD

KIMBLE

GILLESPIE

KERR

BANDERA

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ZAVALA

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SHELBY

PANOLA

HARRISON

GREGG

UPSHUR

CAMP

MORRIS

TITUS

CASS

BOWIE

RED RIVER

LAMAR

FANNIN

GRAYSON

COOKE

MONTAGUE

CLAY

WICHITA

BAYLOR

ARCHER

YOUNG

JACK

PALO PINTO

STEPHENS

SHACKELFORD

THROCKMORTON

JONES

CALLAHAN

TAYLOR

NOLAN

FISHER

KENT

STONEWALL

HASKELL

KNOX

KING

DICKENS

CROSBY

LUBBOCK

HALE

FLOYD

PARMER

CASTRO

DEAF SMITH

OLDHAM

RANDALL

BAILEY

LAMB

HARTLEY

Littlefield
Enochs
Anton No.
Anton-Irish
West Anton
Anton
Lutrick
Petersburg
Abernathy
Arick
Floydada
Cone
Gravens
Morton
Yellow House
Whitharral
Petitt
Shallowater
Smyer No.
Smyer
Idalou
Lorenzo
Ralls
Crosbyton
Lubbock
Lee Harrison
Stennett
Levelland
Hobbs
Smyer
Hobbitzelle
No. Ropes
Ropes
Mallet
Claurene
Slaughter
Sundown
Ropesville
Woodrow
Slaton
Cap Rock
Gertrude Wood
Forbes
Aycock
Sims
Kalgary
Covington
Sec. 83
Terryon
Meadow
Tahoka
Wilson
Sunland
Buenos
Cross
Southland
Splar (ABD)
Alex
Grentice
Cone
Mound Lake (ABD)
P.H.D.
Huntley
Close City
Post
Garza
G.S. Ranch
(ABD) Coroco
Brownfield
Tahoka
Owens West
Owens
Tokio So.
Coroco So/E
Brownfield South
Waples-Platter
Wasson N/W
Wellman S/W
Wellman
Statex
Adair N/E
Corrigan
Corrigan No.
East Corrigan
No. Welch
O'Donnell
Denver City
Venis Seagraves
Seagraves
Seagraves So.
Loop
Welch
Welch So.
Welch S/E
Cedar Lake
Cedar Lake S/E
Mungerville N/W
Mungerville
Felmac
Smith
Adcock
Felken
Showden
Lamesa E
Tredway
North Gail (ABD)
Fluvanna
W. Fluvanna
Fluvanna S/W
Corazon
Varel
Myrtle W.
So. Gail
Myrtle
Revilo
Arah
Lucy
(ABD) Reland Granite
Seminole
Seminole S/W
Riley
Robertson No.
Doss
Wescott
Tobe Jo.
Robertson
Cottenfield
Arrow
Pence
Chilton
Means
Means No.
(ABD) Florey
Flying "N"
Flanagan Westbrook
Harris
Blk 34 N/W
Molley
Mc Farland
Glasco
Mc Farland, E.
Blk 6
Blk 6 E.
Means E.
Mc Farland So.
Fullerton No.
Blk A-34
No. Shafter Lake
East Shafter Lake
Shafter Lake
Shafter Lake (Gas)
Means So.
Ve Andrews
Magutex
Mutex
Andrews
So. Shafter Lake
Deep Rock
Parker
Wemac
Bakke
Nix
Nix So.
Fuhrman Mascho
Fuhrman
Midland Farms N.E.
Fasken (Ell)
Midland Farms No.
So. Andrews
Lowe
Tripple "N"
Clabber Hill
Midland Farms
Fasken
Inspector
No. Cowden
E. Goldsmith
Mac Boring
Midland Farms S/E
Ruth
Schambach
Huffercamp
Germania West
Midland
Lindsey
Huddle-Manning
Wells
Lamesa
Walls
Spraberry
West Spraberry
Fowel
Luck Pot
Mc Mill
Gail S/W
Good
Good N.E.
Spraberry
Arthur
Clara Good
Spraberry
Ackerly
No. Vealmoor
Stripling
Vealmoor
Modesta
Oceanic
Ackerly E.
Luther So.
Luther S.E.
Luther S/W
Luther E.
Vealmoor Read
Vealmoor E.
Vealmoor C.
Vincent Coronet
Vincent
Vincent E.
Sharon Mag.
Wanda
Durn
Colonial Ranch
Reinecke
Gardner
Gardner So.
Allen Holliday
Pancho Mag.
Pancho Mag S.W.
No. Von Roeder
Von Roeder
Apclark
So. Gail
Canning
Diamond M
Sonora
Rhodes
Borden
Gail
Lucy
(ABD) Reland Granite
Big Spring
(ABD) Bond
O'Daniel
Thurso Green
Eagle
Westbrook West
Westbrook
Iatan North
Iatan E. Howard
Maude
Coahoma
Varel
North (ABD)
Big Spring
Hutto
Moore
Snyder
Al Baugh
Stanton
Stanton (ABD)
Glass No.
Glass Spra.
Glass Penn.
Glass Sands
Frin Glass
Howard Glasscock
Mc Dow
Lamesa
Borden
Gail
Lucy
Myrtle
Myrtle W.
Revilo
Arah
Fluvanna
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Varel
Tredway
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Spraberry
Arthur
Clara Good
Spraberry
Ackerly
No. Vealmoor
Stripling
Vealmoor
Modesta
Oceanic
Ackerly E.
Luther So.
Luther S.E.
Luther S/W
Luther E.
Vealmoor Read
Vealmoor E.
Vealmoor C.
Vincent Coronet
Vincent
Vincent E.
Sharon Mag.
Wanda
Durn
Colonial Ranch
Reinecke
Gardner
Gardner So.
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Pancho Mag.
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No. Von Roeder
Von Roeder
Apclark
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Canning
Diamond M
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Lucy
(ABD) Reland Granite
Big Spring
(ABD) Bond
O'Daniel
Thurso Green
Eagle
Westbrook West
Westbrook
Iatan North
Iatan E. Howard
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Varel
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Moore
Snyder
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Stanton (ABD)
Glass No.
Glass Spra.
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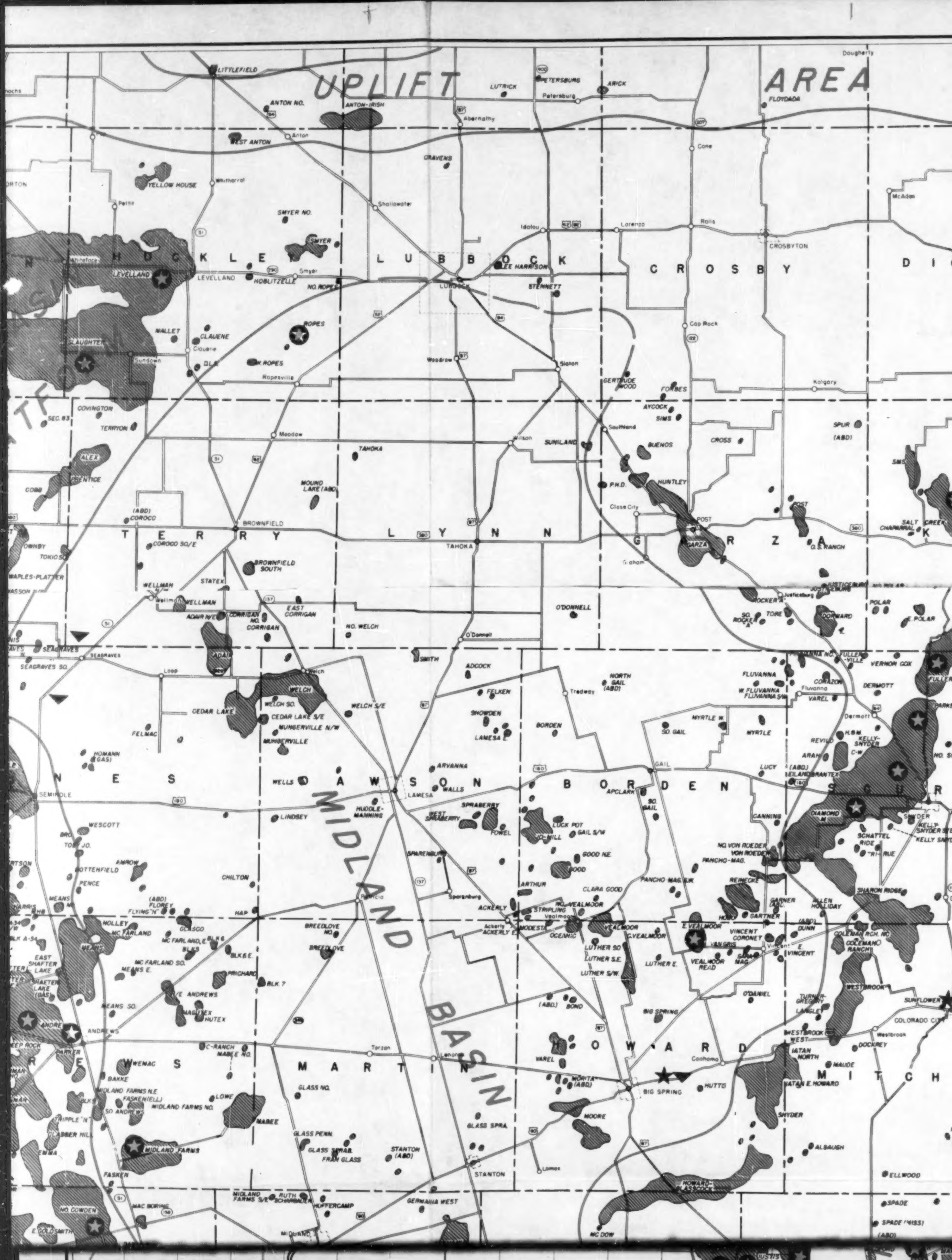
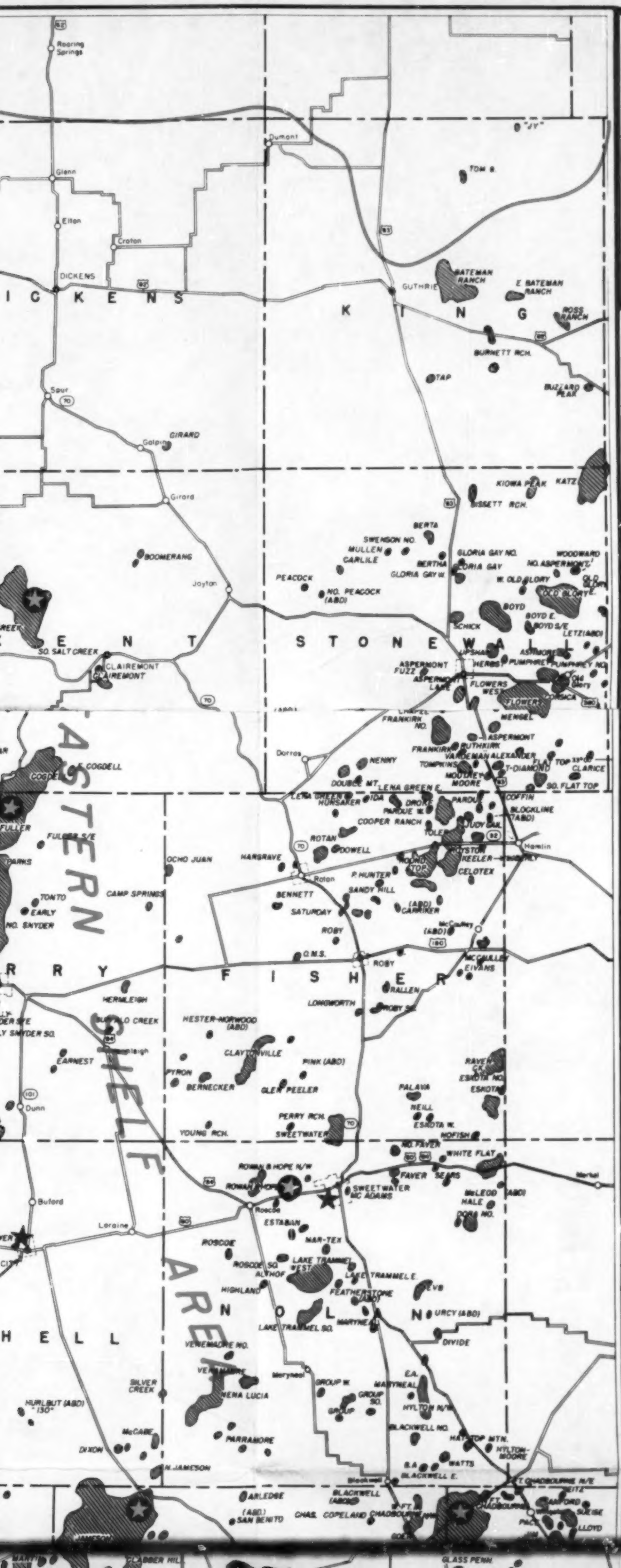
Howard Glasscock
Mc Dow



UPLIFT
AREA
LITTLEFIELD
LUTRICK
PETERSBURG
Petersburg
ARICK
Dougherty
FLOYDADA
ANTON NO.
ANTON-IRISH
Abernathy
WEST ANTON
Anton
CRAVENS
Cone
YELLOW HOUSE
Whitharral
Pettit
McAdoo
Shallowater
SMYER NO.
SMYER
Idalou
Lorenzo
Ralls
CROSBYTON
Whiteface
LEVELLAND
HOCKLEY
LUBBOCK
CROSBY
LEE HARRISON
Smyer
HOBLITZELLE
NO. ROPES
LUBBOCK
STENNETT
ROPES
MALLET
CLAUENE
Clauene
SLAUGHTER
Sundown
D.L.S.
W. ROPES
Woodrow
Slaton
Cap Rock
GERTRUDE WOOD
FORBES
Ropesville
Kalgary
COVINGTON
SEC. 83
TERRYON
AYCOCK
SIMS
SPUR (ABD)
Meadow
Southland
Wilson
SUNILAND
BUENOS
CROSS
TAHOKA
ALEX
PRENTICE
COBB
MOUND LAKE (ABD)
HUNTLEY
P.H.D.
Close City
(ABD) COROCO
BROWNFIELD
POST
TERRY
LYNN
GARZA
TAHOKA
SALT CREEK
CHAPARRAL
O.S. RANCH
OWNBY
TOKIO SO.
COROCO SO/E
BROWNFIELD SOUTH
Graham
WAPLES-PLATTER
WELLMAN N/W
STATEX
Wellman
WELLMAN
ADAIR N/E
CORRIGAN NO. CORRIGAN
EAST CORRIGAN
O'DONNELL
ROCKER "A"
Justiceburg
SO. ROCKER "A"
TORE
DORWARD
POLAR
E. POLAR
NO. WELCH
O'Donnell
SEAGRAVES
SEAGRAVES SO.
ADAIR
Loop
Welch
SMITH
ADCOCK
NORTH GAIL (ABD)
FLUVANNA
FULLER-VILLE
VERNON COX
WELCH
WELCH SO.
FELKEN
Tredway
W. FLUVANNA
FLUVANNA S/W
Fluvanna
CORAZON
VAREL
DERMOTT
CEDAR LAKE
CEDAR LAKE S/E
WELCH S/E
MUNGERVILLE N/W
MUNGERVILLE
SNOWDEN
LAMESA E.
BORDEN
MYRTLE W.
SO. GAIL
MYRTLE
Dermott
FELMAC
HOMANN (GAS)
H.B.M.
KELLY-SNYDER
REVILO
C-W
ARAH
ARVANNA
LUCY
(ABD) EILAND BRANTEX
GAIL
WELLS
DAWSON
BORDEN
SEMINOLE
LAMESA
WALLS
APCLARK
SO. GAIL
HUDDLE-MANNING
SPRABERRY
WEST SPRABERRY
LINDSEY
MIDLAND
WESCOTT
LUCK POT
GAIL S/W
CANNING
DIAMOND M
SNYDER
KELLY-SNYDER
SCHATTEL RIDE
KELLY SNYDER
TOBY JO.
FOWEL
"RI-RUE"
NO. VON ROEDER
VON ROEDER
GOOD N.E.
AMROW
SPARENBURG
PANCHO-MAG.
BOTTENFIELD
PENCE
GOOD
CHILTON
ARTHUR
PANCHO-MAG S.W.
REINECKE
MEANS
CLARA GOOD
SHARON RIDGE
(ABD) FLOREY
FLYING "N"
Patricio
Sparenburg
GARNER (ABD)
ALLEN HOLLIDAY
HAP
ACKERLY
NO. VEALMOOR
STRIPLING
Vealmoor
NOLLEY
MC FARLAND
GLASCO
BREEDLOVE NO.
Ackerly
ACKERLY E.
MODESTA
OCEANIC
VEALMOOR
E. VEALMOOR
VINCENT CORONET
(ABD) DUNN
COLEMAN RCH. NO.
EAST SHAFTER LAKE
MC FARLAND, E.
BLK 6
BLK 5
BLK 6 E.
BREEDLOVE
C. VEALMOOR
LUTHER SO.
LUTHER S.E.
VAN GRIS
Vincent
E. VINCENT
COLEMAN RANCH
MC FARLAND SO.
MEANS E.
PRICHARD
BLK 7
LUTHER E.
VEALMOOR READ
SUGG MAG.
SHAFTER LAKE (GAS)
S/E ANDREWS
LUTHER S/W.
WESTBROOK
O'DANIEL
TURNER-GREGORY
LANGLEY
SUNFLOWER
MAGUTEX
HUTEX
MEANS SO.
(ABD.)
BOND
BIG SPRING
COLORADO CITY
ANDREWS
Westbrook
WESTBROOK WEST
DEEP ROCK
PARKER
C-RANCH
MABEE NO.
Tarzan
HOWARD
IATAN NORTH
DOCKREY
WENAC
MARTIN
Lenorah
VAREL
Coahoma
MAUDE
BAKKE
MIDLAND FARMS N.E.
FASKEN (ELL.)
GLASS NO.
BASIN
MORITA (ABD)
BIG SPRING
HUTTO
IATAN E. HOWARD
MITCH
SO. ANDREWS
MIDLAND FARMS NO.
LOWE
MABEE
TRIPPLE "N"
MOORE
SNYDER
GLASS SPRA.
GLABBER HILL
GLASS PENN.
EMMA
MIDLAND FARMS
GLASS SPRAB.
FRAN GLASS
STANTON (ABD)
ALBAUGH
FASKEN
STANTON
Lomax
ELLWOOD
MIDLAND FARMS S/E
RUTH SCHARBAUER
HOWARD-GLASSCOCK
MAC BORING
HUFFERCAMP
GERMANIA WEST
SPADE
NO. COWDEN
SPADE (MISS)
(ABD)
E. GOLDSMITH
MIDLAND
MC DOW



Base map furnished by
and extra copies available
from Midland Map Company,
Box 1211, Midland, Texas

$2.50 each

Oil and Gas Fields of the Permian Basin in WEST TEXAS

DELAWARE BASIN

LOVING

WINKLER

REEVES

JEFF DAVIS

BREWSTER

PECOS

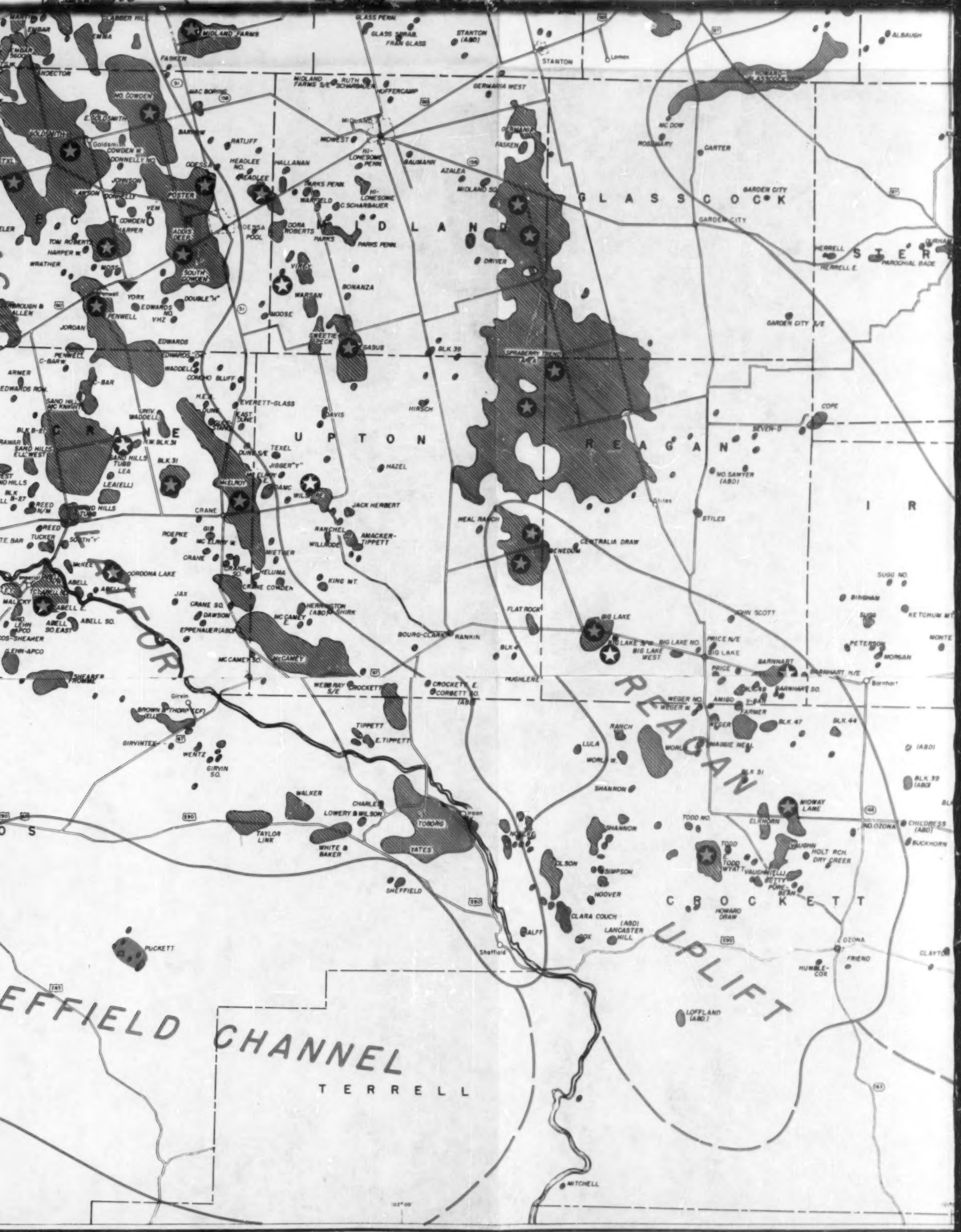
Legend

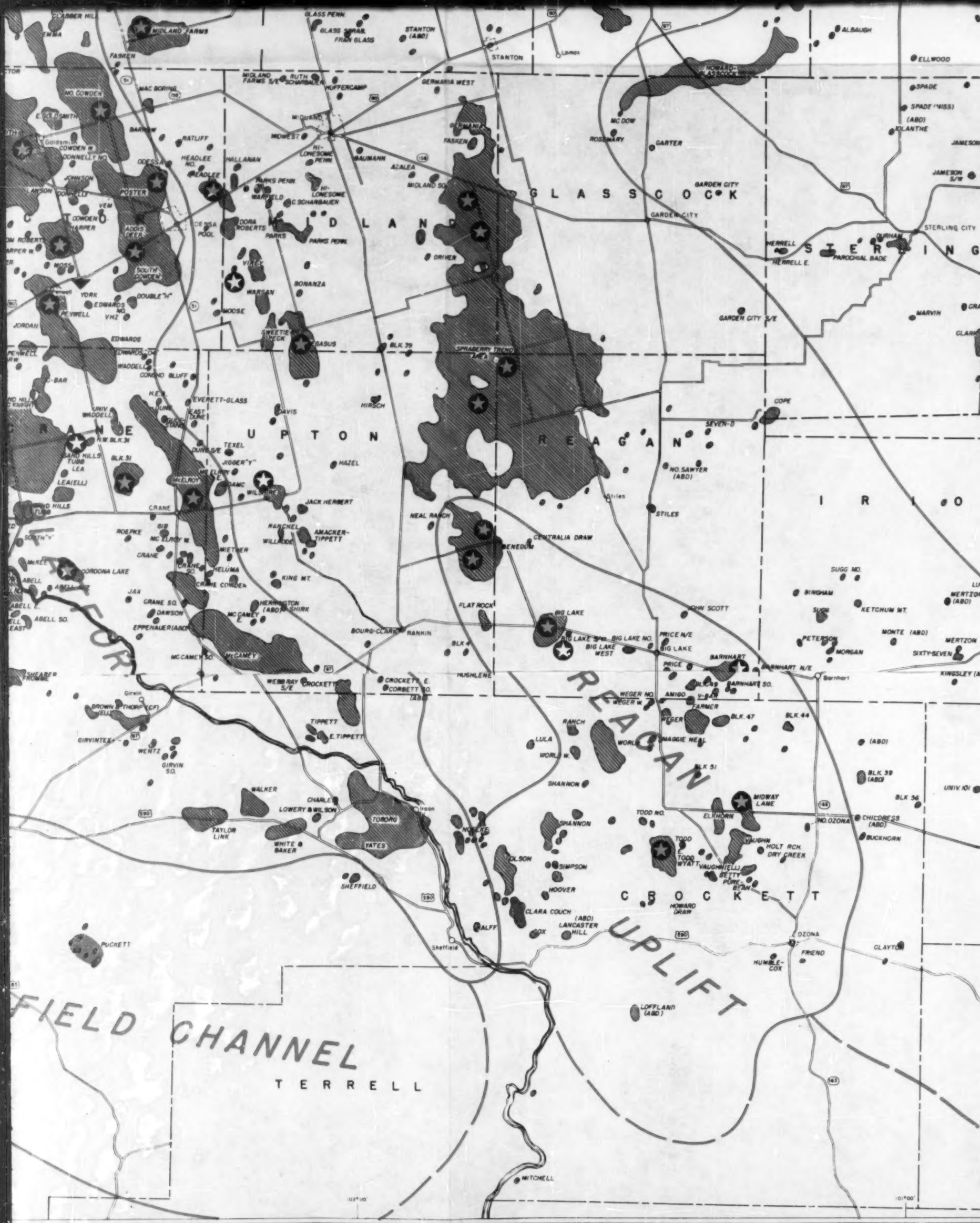
- OIL FIELDS
- GAS FIELDS
- REFINERIES
- GASOLINE PLANTS
- CARBON BLACK PLANTS

NOTE: Fields not labeled are recent discoveries and have not been officially named.

SCALE IN MILES

0 5 10 20


MIDLAND FARMS
GLASS PENN
GLASS SAMAR
FRAN GLASS
STANTON (ABD)
STANTON
ALBAUGH
FASKEN
MIDLAND FARMS S/E
RUTH SCHARBAUER
HUFFCAMP
GERMANIA WEST
MAC BORING
NO. COWDEN
E. GOLDSMITH
GOLDSMITH
BARROW
RATLIFF
Goldsmith
COWDEN W.
DONNELLY NO.
MIDWEST
HI-LONESOME PENN
BAUMANN
GERMANIA
FASKEN
MC DOW
ROSEMARY
CARTER
ODESSA
HEADLEE NO.
HALLANAN
HEADLEE
AZALEA
JOHNSON
LAWSON
DONNELLY
FOSTER
PARKS PENN
HI-LONESOME
MIDLAND SO.
GARDEN CITY
GLASSCOCK
COWDEN
HARPER
ADDIS DEEP
ODESSA POOL
DORA ROBERTS
PARKS
PARKS PENN
MIDLAND
TOM ROBERTS
HARPER W.
WRATHER
MOSS
SOUTH COWDEN
VIRGIL
DRIVER
HERRELL
HERRELL E.
PAROCHIAL BADE
YORK
EDWARDS NO.
VHZ
DOUBLE "W"
WARSAN
BONANZA
PENWELL
MOOSE
JORDAN
EDWARDS
SWEETIE PECK
GASUS
BLK 39
SPRABERRY TREND AREA
GARDEN CITY S/E
PENWELL
C-BAR W.
WADDELL
COMANCHE BLUFF
ARMER
C-BAR
EDWARDS ROW
SAND HILLS MC KNIGHT
EVERETT-GLASS
EAST DUNE
DAVIS
HIRSCH
COPE
SILVER-B
CRANE
UNIV. WADDELL
BLK B-27
N.W. BLK 31
SAND HILLS ELL WEST
SAND HILLS TUBB
LEA
LEA (ELL)
BLK 31
DUNE S/E
TEXEL
JIGGER "Y"
HAZEL
UPTON
REAGAN
NO. SAWYER (ABD)
McELROY
McELROY E.
WILSHIRE
REED N/M
CRANE
JACK HERBERT
STILES
MEAL RANCH
REED
TUCKER
SOUTH "Y"
ROEPKE
GIB
McELROY W.
RANCHEL
WILLARD
AMACKER-TIPPETT
CENTRALIA DRAW
BENEDUM
CRANE
MIETTER
CORDOVA LAKE
HELUMA
CRANE CO.
CRANE COWDEN
KING MT.
SUGG NO.
BINGHAM
SUGG
KETCHUM MT.
McKEE
ABELL
ABELL E.
ABELL SO.
ABELL SO. EAST
JAX
CRANE SO.
DAWSON
EPPENAUER (ABO)
HERRINGTON (ABO)
SHIRK
McCAMEY E.
JOHN SCOTT
FLAT ROCK
BIG LAKE
BIG LAKE S/W.
BIG LAKE NO.
BIG LAKE WEST
PRICE N/E
PRICE
BIG LAKE
PETERSON
MORGAN
MONTE
BARNHART
BARNHART N/E
BARNHART SO.
Barnhart
LEHN-APCO
SHEARER
McCAMEY SO.
McCAMEY
WEMBLEY S/E
CROCKETT
CROCKETT E.
CORBETT SO. (ABO)
HUGHLENE
BOURG-CLARK
RANKIN
BLK 4
MUEHLENE
WEGER NO.
WEGER W.
AMIGO
V-BAR
FARMER
WEGER
BLK 47
BLK 44
RANCH
LULA
WORLEY
WORLEY W.
MAGGIE MAE
BLK 51
SHANNON
MIDWAY LANE
ELKHORN
TODD NO.
NO. OZONA
CHILDRESS (ABO)
BUCKHORN
TODD
E. TODD
WYATT
VAUGHN
VAUGHN (ELL)
HOLT RCH.
DRY CREEK
BETTY PURE-BERN
OLSON
SIMPSON
HOOVER
CLARA COUCH
HOWARD DRAW
COX
ALFF
LANCASTER (ABD) HILL
OZONA
FRIEND
HUMBLE-COX
CLAYTON
LOFFLAND (ABO)
MITCHELL
GIRVIN
BROWN (ELL)
THORP (CF)
GIRVINTEX
WENTZ
GIRVIN SO.
TIPPETT
E. TIPPETT
WALKER
CHARLES LOWERY & WILSON
TOBORG
YATES
TAYLOR LINK
WHITE & BAKER
SHEFFIELD
Sheffield
PUCKETT
FOR
REAGAN
UPLIFT
SHEFFIELD CHANNEL
TERRELL
102°00'


GLASS PENN
GLASS SPRAB. FRAN GLASS
STANTON (ABO)
STANTON
Lamesa
ALBAUGH
ELLWOOD
MIDLAND FARMS
FASKEN
MIDLAND FARMS S/E
RUTH SCHWARTZ
HUFFCAMP
GERMANIA WEST
MAC BORNE
NO. COWDEN
E. COWDEN
BARROW
RATLIFF
MIDWEST
HI-LONESOME PENN
GERMANIA
FASKEN
MC DOW
ROSEMARY
GARTER
SPADE
SPADE (MISS) (ABO)
IOLANTHE
JAMESON
JAMESON S/W
ODESSA
HEADLEE NO.
HEADLEE
HALLANAN
BAUMANN
AZALEA
MIDLAND SO.
GARDEN CITY
GLASSCOCK
JOHNSON
LARSON
FOSTER
PARKS PENN
WARFIELD
HI-LONESOME
C. SCHARBAUER
COWDEN HARPER
ADDIS DEEP
DESSA POOL
DORA ROBERTS
PARKS
PARKS PENN
MIDLAND
DRIVER
STERLING CITY
HERRELL
HERRELL E.
PARADOCIAL BADE
STERLING
SOUTH COWDEN
VEST
BONANZA
WARSAN
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RANCHEL WILLDOCK
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SUGG NO.
BINGHAM
KETCHUM MT.
MONTE (ABO)
MERTZON (ABO)
SIXTY-SEVEN
PETERSON
MORGAN
PRICE N/E
BIG LAKE
BIG LAKE NO.
BIG LAKE WEST
BARNHART
PRICE
BARNHART N/E
Barnhart
BARNHART SO.
HUGHLENE
CROCKETT
CROCKETT E. CORBETT SO. (ABO)
WEBB RAY S/E
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SHANNON
(ABO)
BLK 39 (ABO)
UNIV 101
BLK 56
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TODD
TODD WYATT
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VAUGHN (ELL)
HOLT RCH. DRY CREEK
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HOOVER
COLSON
CLARA COUCH
(ABO) LANCASTER HILL
HOWARD DRAW
REAGAN UPLIFT
CROCKETT
OZONA
FRIEND
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SHEFFIELD
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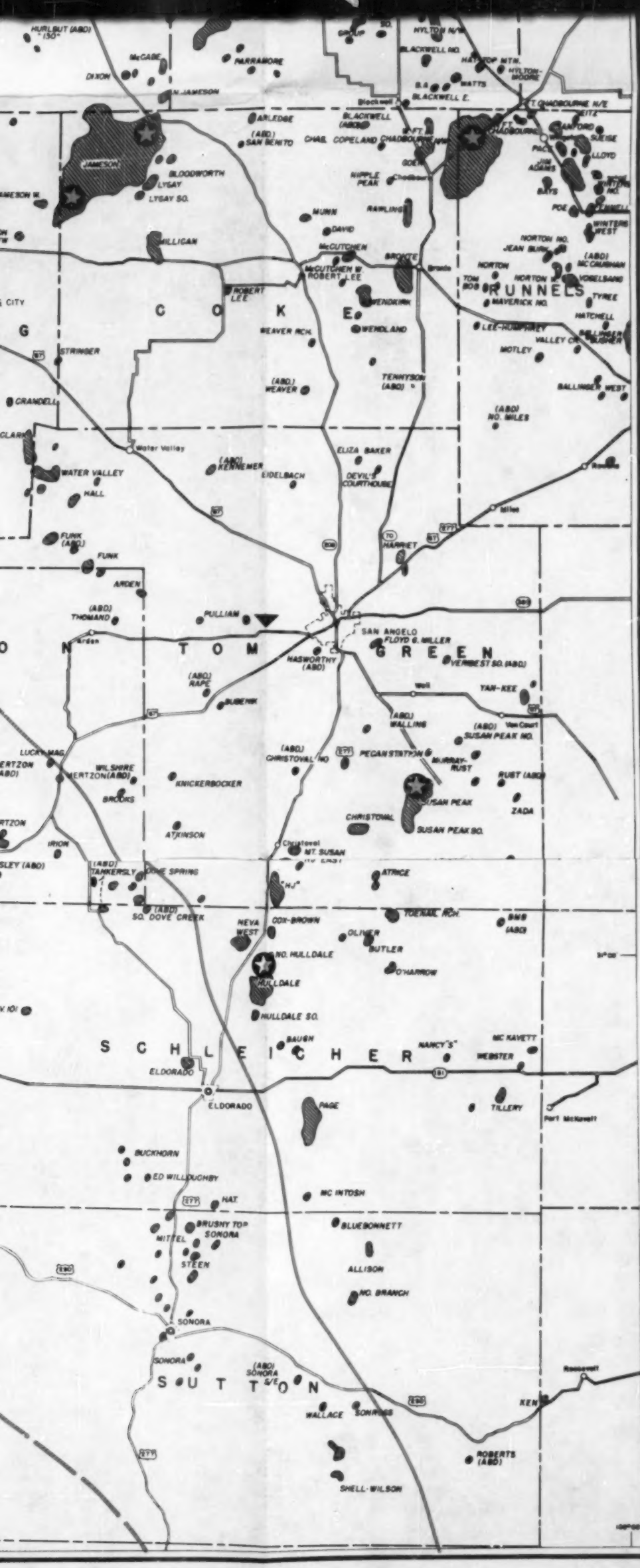
ALFF
COX
PUCKETT
FORT STOCKTON
FIELD CHANNEL
TERRELL
MITCHELL
102°00'
101°00'



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